Passive Design Strategies for the Modern Low-rise Open Office Building in the New York Metro Area

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May 2013

Submitted towards the fulfillment of the requirements for the Doctor of Architecture Degree.

School of Architecture
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Doctorate Project Committee
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We certify that we have read this Doctorate Project and that, in our opinion, it is satisfactory in scope and quality in partial fulfillment for the degree of Doctor of Architecture in the School of Architecture, University of Hawai'i at Mānoa.

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Introduction

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Introduction:

The modern low-rise (six stories or less) open office building envelope serves as a divider that separates indoor and outdoor space and provides many practical functions. Some of these functions include protecting one from the elements, maintaining a thermal barrier, providing views, shading and day-lighting. The building envelope also has the capacity to act as a sound buffer, withstand structural forces of wind, dead and live loads.[1] Overall, the building envelope is intended to promote the well-being of the indoor occupants by considering micro and macro environmental conditions which are expressed through form and function. This complexity is considered to be "a highly specialized science and art" (Syed 2012).[2] Therefore, the objective of this research is to determine if some of these practical considerations can be done in a more sustainable way. Attention will be given to existing office buildings in the New York Metropolitan (Metro) area as shown in Figure 1. Concepts of day-lighting, shading, solar radiation and promoting the use of natural ventilation will be studied based on their typologies in order to find the most effective solution for a retrofit project. These passive design strategies should be economical, adaptable, and have an impact upon reducing energy consumption for the modern low-rise open office building (MLOOB) in a variable climate. Additionally, these considerations must offer the opportunity to improve occupant comfort which will also be discussed.

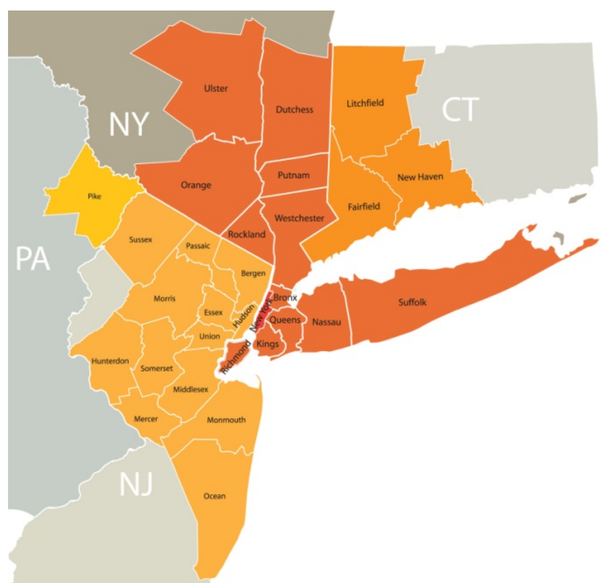

Figure 1: New York Metropolitan Area Map
Source: http://www.selectleaders.com

According to climate data, existing MLOOB envelopes in the New York Metro

[1] Scott Murray, *Contemporary Curtain Wall Architecture*, (New York: Princeton, 2009), 1-10.
[2] Asif Syed, *Advanced Building Technologies for Sustainability*, (Hoboken: Wiley, 2012), 115.

area encounter mixed climate conditions.[3] Since the façade to floor area ratio is generally high for this building type, substantial energy usage is affected by the building envelope. Respectively, this project will define passive design strategies for the building façade.

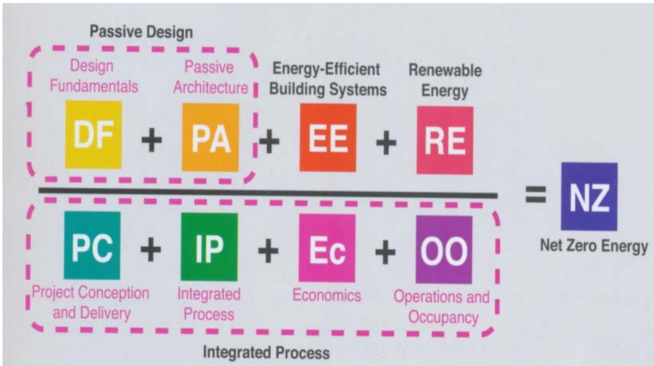

Figure 2: Integrated Passive Design Process as Part of a Net Zero Energy Equation (As Outlined by Dashed Lines)
Source: Hootman 2012.

The overall goal is to determine the most efficient strategy to improve occupant comfort while reducing energy use. This approach is considered to be "a fundamental component of the integrated design process" which is used to create net-zero energy buildings (Hootman 2013).[4] This practice is outlined by dashed areas in Figure 2. Climatic subjects of solar radiation, prevailing wind direction/speed, heating and cooling degree days, among other data will be collected. The efficiency of each passive design retrofit typology will be analyzed for the basis of these environmental conditions. Although energy use related to heating requirements is substantially more than cooling, it is well understood that relatively few options exist to decrease heat loss without substantially modifying an existing building envelope.[5]

When determining measures of improvement, an existing building without passive techniques will be compared to the same building with a proposed facade retrofit. This modification will consider adding exterior shading devices, light shelves and operable windows as these are common passive design strategies. Each design typology will be described by its merits so that the modern low-rise building designer can take an intuitive approach when strategizing a proposed energy retrofit for similar office buildings in the future. This step will occur prior to conducting computer aided environmental analysis on the basis that software does not have the capability to find the best combined passive design strategy. Environmental analysis is being undertaken in

[3] Ibid., 120-121.
[4] Tom Hootman, *Net Zero Energy Design: A Guide for Commercial Architecture*, (Hoboken: Wiley, 2012), XVI-XIX.
[5] Lisa Gelfand, and Chris Duncan, *Sustainable Renovation Strategies for Commercial Building Systems and Envelope*, (Hoboken: Wiley, 2012), 86.

order to quantify energy use reduction based on the most efficient retrofit. By investigating and endorsing passive strategies as the ideal alternative, this research promotes sustainability for the MLOOB envelope at a greater scale. This is especially important if development of this building typology continues in the New York Metro area.

By combining previously known passive building envelope strategies and further researching how each of them relate, a composite passive design typology that reduces energy use can be formulated. This research methodology will start with analyzing thermal comfort criteria followed by existing climate data for the New York Metro area. Next will be the objective of defining the typical MLOOB typology, specifically that which is most common. After these foundational steps, passive design typologies for shading devices, light shelves and operable windows will undergo examination. The objective is then to narrow these down to the most efficient form that can be used for a retrofit. Once this goal is accomplished, this form can then be modeled and tested for its performance. Triangulation of existing building envelope information, passive design typologies and climate data will facilitate the means for future environmental analysis.

By use of computer aided programs one can model the subject building and the proposed retrofit. Of the limited qualified computer software available for combined building and climate analysis, Autodesk Ecotect 2011 will be used. This program enables analysis and visualization methods when applying strategies for shading, solar radiation, day-lighting, natural ventilation, thermal comfort and occupant views. Optionally, the retrofit may be altered at different stages based on the results of environmental analysis. This last phase may be the most important, as tweaking the proposed retrofit will have compounding effects. By comparing baseline energy use information for the commercial sector one can calculate estimated energy savings based on the proposed retrofit. Minimizing energy consumption related to these subjects will lessen electricity use, preserve natural resources and lower greenhouse gas emissions. This is of importance as the "United States commercial energy sector constitutes nearly 18% of US energy consumption" (Syed 2012).[6]

Modern low-rise open office building typologies built from 1970's through present will be studied. By selecting a single symbolic building for analysis, one may reduce the complexities of additional variables including building orientation, space planning and landscape factors. Site surveying may be necessary in order to provide relative research for the strategies associated with the existing building envelope. This process will inevitably require review of construction drawings that may be on file with appropriate city or state agencies.

Studies of how landscape and climate affect a building envelope will be relevant. Calculating the impacts of heat loss/gain, day-lighting, natural ventilation and shading can be done by computer applications and manually, as required. This will be included as part of the research and design component to this project. Conditions of feasibility will quantified as financial investments are limited. Payback periods based on initial investments must be reasonable for an office building owner to consider. Since practicality is a primary concern, this research topic is aimed to help those who specialize in design services that use economical passive strategies to conserve energy. While this project targets the modern low-rise open office building typology, the strategy for other building types is similar.

[6] Syed, *Advanced Building Technologies*, 2.

Building
Envelope Principles

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Occupant Comfort:

Modern commercial office building envelopes provide many practical functions. The common assumption is that insulation is the primary component in maintaining the building envelope thermal barrier. While the law of thermodynamics states that higher material resistance values (R-values) take longer to transmit temperatures from hot to cold, there are additional criteria for thermal conditions (Hinrichs et al. 2006).[7] Alternatively, one will discover that material selection is only a small part of the overall strategy in designing an efficient building envelope which promotes occupant comfort. One must investigate environmental conditions and how they play a part in the orchestration of reducing energy consumption while providing a comfortable workspace.

Thermal comfort correlates to the subject prepared by the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) and the American National Standards Institute (ANSI) as Thermal Environmental Conditions for Human Occupancy Standard 55-2004. This resource identifies "combinations of thermal, environmental, and personal factors to provide acceptable standards for a majority of occupants" (ASHRAE 2004).[8] ASHRAE's comprehensive approach is preferred rather than strictly selecting building materials based on their finishes and thermal resistance values. Section 55-2004 is divided into six subject areas including metabolic rate, air temperature, radiant temperature, clothing insulation, air speed and humidity (ASHRAE

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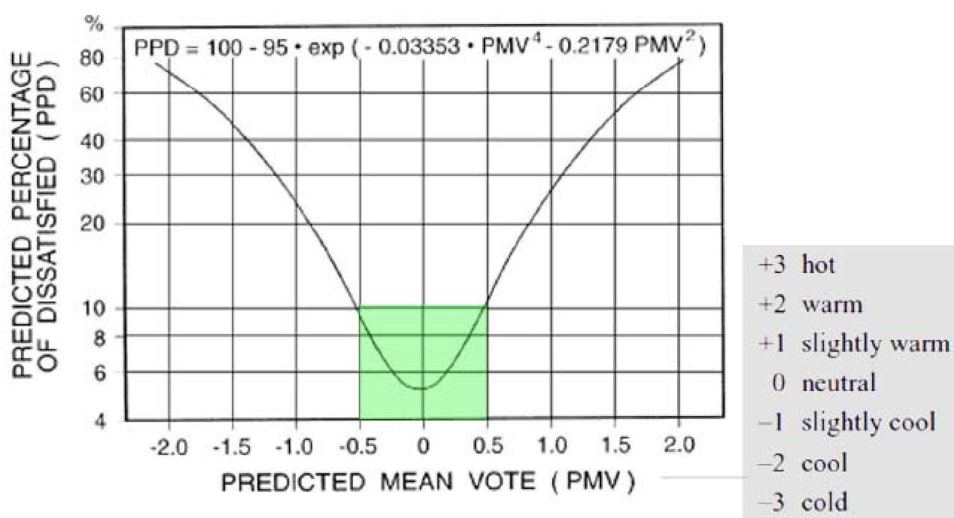
[7] Roger Hinrichs, and Merlin Kleinbach, *Energy, Its Use and the Environment: Fourth Edition*, (Belmont, CA: Thomson Brooks/Cole, 2006), 106-109.
[8] "ANSI/ASHRAE Standard 55-2004: Thermal Environmental Conditions for Human Occupancy," American Society of Heating, Refrigerating and Air Conditioning Engineers Inc., last modified 2004, http://www.ashrae.org.

2004).[9] These subjects correlate to strategic selection of passive shading, day-lighting, solar radiation and natural ventilation strategies in addition to personal measures for adjusting thermal comfort. Moreover, these subjects provide grounds to study the effects of heat loss and heat gain through the building envelope. This subject is part of the equation in determining occupant comfort whereby British Thermal Units (Btu's) can be studied in terms of energy use and savings. ASHRAE promotes the use of graphical methods to analyze thermal comfort for these subjects.[10] They are prepared in regard to a Predicted Mean Vote (PMV) as seen in Figure 3. This provides an index of an acceptable thermal environment for general occupant comfort levels in a space. It uses heat balance



Predicted percentage dissatisfied (PPD) as a function of predicted mean vote (PMV).

Acceptable Thermal Environment for General Comfort

PPD	PMV Range
< 10	-0.5 < PMV < + 0.5

Figure 3: Predicted Percentage Dissatisfied (PPD) as a Function of Predicted Mean Vote (PMV)
Source: ASHRAE Standard 55-2004, Table 5.2.1.2.

[9] Ibid.
[10] "ANSI/ASHRAE Standard 55-2004," ASHRAE Inc., last modified 2004.

principles which are correlated to the six subject areas of Section 55-2004 and estimates occupant response based on how comfortable they feel. This index is indicated by a seven-point scale, though truncated from -2.5 to +2.5 on the graph. It represents the predicted percentage of people that would be dissatisfied (PPD) based on the key thermal conditions discussed earlier. There are seven points of the scale by which people categorize thermal comfort and by which ASHRAE determines this standard. ASHRAE's thermal sensation scale description ranges from +3 as Hot, 0 as the neutral ideal value and -3 as Cold. This suggests that a PMV range of -0.5 to +0.5 is considered acceptable.[11] This level of acceptability is represented by the PPD prediction of less than 10% of people being dissatisfied. Additionally, when referencing Figure 3, the bottom area of the curve (as indicated in green) represents the most ideal thermal conditions which ASHRAE recommends.[12]

Based on ASHRAE's Acceptable Range of Operating Temperatures, Figure 4, it has been interpreted that an indoor temperature between 67.5 degrees Fahrenheit (°F) and 79 °F is within the realm of what is acceptable. This also shows a specific humidity (SH) ratio of 0.012 or less, without a minimal limit. The SH, which is a ratio of the mass of water vapor content to air content, correlates with operative temperatures and relative humidity (RH) percentage curves as shown. Although the operative temperature span is large, the "ideal temperature" would fall directly in the center of the rhombus-shaped PMV hatched area. When found, this indicates the SH limit with respect to operative temperature (OT). To pinpoint the ideal location on this chart, SH would be at a 0.006 vapor to air ratio whereby RH is between 30-35%. This also translates to an OT of 72.5

[11] "ANSI/ASHRAE Standard 55-2004," ASHRAE Inc., last modified 2004.
[12] Ibid.

°F and a dewpoint temperature (DT) of 43.5 °F. Lastly, and more importantly, this graph indicates that when RH percentages are higher, indoor operating temperatures should decrease, and vice versa. While it is important to note that the subject of humidity will not be of primary focus to this research project, it does share importance by which the ideal RH percentage should not be grossly exceeded during any indoor environmental condition. This key rule applies whether a building is passively and/or actively conditioned to achieve thermal comfort.

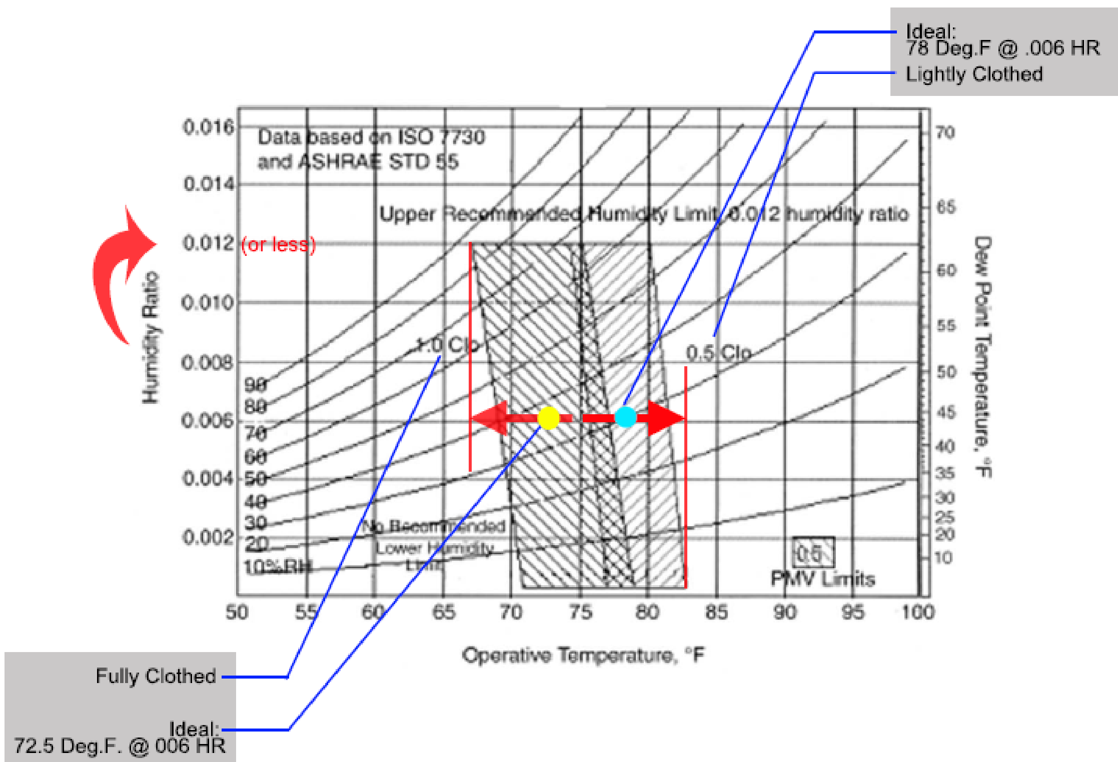
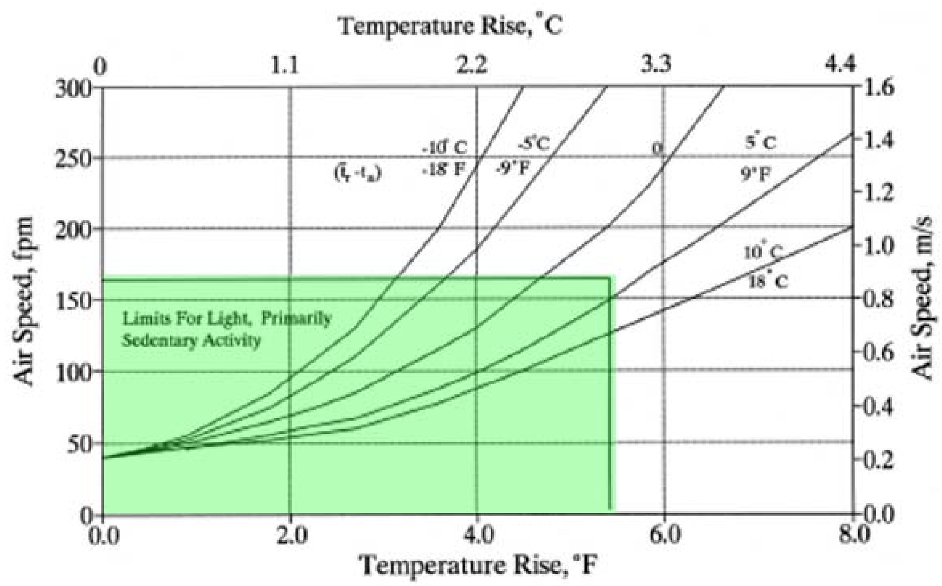


Figure 4: Acceptable Range of Operative Temperature and Humidity
Source: ASHRAE Standard 55-2004, Table 5.2.1.1.

Subsequently it is then logical to question when to begin cooling and heating an office space in the New York Metro area. Accordingly, an office air and radiant temperature of 75 °F, 50% RH with an air speed of 40 feet per minute (FPM) or less, is a common temperature to begin cooling (Lynch 2008).[13] According to Brian Lynch, "to offset the use of changing a thermostat by -1.0 °F saves approximately 2.0% of cooling energy per 1.0 °F."[14] The method of offsetting the use of a thermostat for cooling can be achieved by introducing a higher rate of air movement through a space. Figure 5 illustrates this by a temperature rise of 5.4 °F being offset by an air speed of 165 FPM. While it is suggested that with the use of operable windows one can help to achieve increased air movement within a space, further studies are required. In view of this, one should determine how this method can be used passively. This is rather than using mechanically operated cooling devices; namely active air conditioning.



Note: Curved lines depict increased air temperature offsets (-°F) by increased air speeds (+fpm) as this graph is truncated from 0°F to 8°F. Air speeds above 165 fpm are not considered practical within office environments and is therefore shown without green shading.

Figure 5: Air Speed Required To Offset Increased Occupant Temperature
Source: ASHRAE Standard 55-2004, Figure 5.2.3.

[13] Lynch, Brian and Michael O'Rourke. Big Ass Fans, Inc., "ANSI/ASHRAE 55-2004 Thermal Environmental Conditions for Human Occupancy," last modified April 14, 2008.
[14] Ibid.

Even after the use of air speed to offset increased temperature is utilized, there are still other strategies to passively control the temperature in an office environment. As indicated in ASHRAE's Table B1 (Figure 6), clothing insulation values are relative to how much an occupant can control their own comfort before active air conditioning should take place.[15] For men, the clothing insulation factor (I_{cl}) of 0.57; trousers, short sleeve shirt versus the normal full attire factor of 1.01; trousers, short sleeve shirt, long sleeve sweater has the potential for the human body to realize a difference of 6 °F in the same environment (Lynch 2008).[16] The I_{cl} is slightly different for women who may wear other types of attire in the office. From Figure 6, women who wear a knee length skirt

Clothing Description	Garments Included[b]	I_{cl} (clo)
Trousers	1) Trousers, short-sleeve shirt	$\boxed{0.57}$
	2) Trousers, long-sleeve shirt	0.61
	3) #2 plus suit jacket	0.96
	4) #2 plus suit jacket, vest, T-shirt	1.14
	5) #2 plus long-sleeve sweater, T-shirt	$\boxed{1.01}$
	6) #5 plus suit jacket, long underwear bottoms	1.30
Skirts/Dresses	7) Knee-length skirt, short-sleeve shirt (sandals)	$\boxed{0.54}$
	8) Knee-length skirt, long-sleeve shirt, full slip	0.67
	9) Knee-length skirt, long-sleeve shirt, half slip, long-sleeve sweater	1.10
	10) Knee-length skirt, long-sleeve shirt, half slip, suit jacket	$\boxed{1.04}$
	11) Ankle-length skirt, long-sleeve shirt, suit jacket	1.10

Figure 6: Clothing Insulation Values (I_{cl}) for Typical Office Ensembles
Source: ASHRAE Standard 55-2004, Table B1.

and short sleeve shirt with sandals have a 0.54 I_{cl}. In contrast, those who wear a knee length skirt, long sleeve shirt, half-slip and suit jacket have a 1.04 I_{cl}. This difference offers the capacity to realize a 6.0 °F "real feel" temperature change. Solar radiation and

[15] "ANSI/ASHRAE Standard 55-2004," ASHRAE Inc., last modified 2004.
[16] Lynch and O'Rourke, "ANSI/ASHRAE 55-2004," last modified 2008.

shading factors are not accounted for in these measures. This variation represents occupant clothing and wind speed adjustment for temperature offset only.

For the basis of thermal comfort, an ideal temperature of 72°F (baseline) will be used. According to air speed offset data, combined with clothing insulation factors, office occupants are capable of manipulating their own thermal comfort by approximately 11.0°F. Adding 11.0°F to the 72°F baseline, equals 83 °F; indicating this warmth should not be of major concern, as it can be offset. As mentioned earlier, this is possible with air movement of 165 FPM, which equates to 1.63kts, or 1.8mph. According to wind rose and average mean wind speed data for the New York Metro area, this amount occurs 100% of the time between the hours of sunrise to sunset throughout warmer periods of the year.[17]

Using day-lighting, shading, solar radiation and natural ventilation strategies together to passively moderate interior office temperatures is a difficult equilibrium to achieve. "Local discomforts should be avoided when trying to maintain thermal comfort" (Lynch 2008).[18] Factors of heat absorption, air temperature rise, and floor/wall surface temperatures will fluctuate based on environmental conditions and with time. Also, drafts through building envelope seals, doors and windows will vary in pressure and temperature, moving from hot to cold. The International Standards Organization (ISO) Standard 7730 defines a draft as "unwanted localized cooling" (Lynch 2008).[19] During cooler seasons this is an important factor that needs to be minimized. Accordingly,

[17] National Oceanic and Atmospheric Administration. "Mean Wind Speed (Kts) - New York La Guardia Airport," Accessed February 22, 2012.
[18] Lynch and O'Rourke, "ANSI/ASHRAE 55-2004," last modified 2008.
[19] Ibid.

acceptable operating temperatures for naturally conditioned spaces are determined from Equation 1.

<u>Equation 1:</u>

$$T_{oc} = 66 + 0.255\,(T_{out} - 32)\ °F. \qquad \text{(ASHRAE 2004)}^{20}$$

Where; T_{oc} is the acceptable operating temperature for occupant comfort, and;

T_{out} is the outdoor air temperature at a specific time of day.

Note: This equation considers occupants wearing appropriate clothing based on temperature/ clothing insulation factors as well as cooling from natural ventilation.

To summarize the concept of thermal comfort is to understand the effects of air temperature, relative humidity, clothing insulation value, metabolic rates, and radiant temperatures all with respect to the human body's relative level of comfort. It should not be considered precisely comfortable for all occupants, but intended to promote a good level of comfort for a majority of occupants.[21] While there are many factors to consider and perhaps this subject can

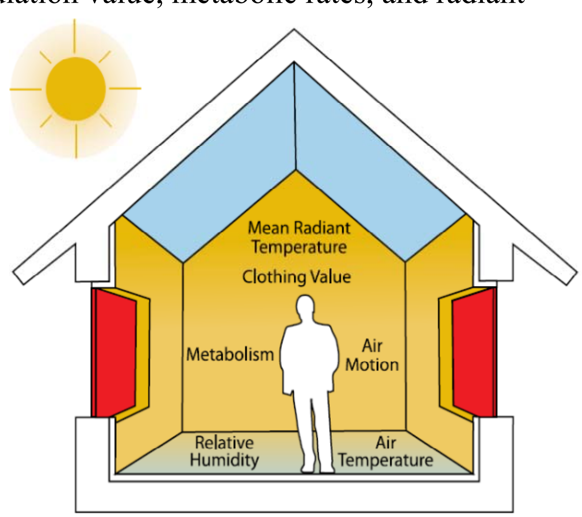


Figure 7: Measures of Thermal Comfort
Source: Passive Design Toolkit, 2008.

[20] "ANSI/ASHRAE Standard 55-2004," ASHRAE Inc., last modified 2004.
[21] "ANSI/ASHRAE Standard 55-2004," ASHRAE Inc., last modified 2004.

be further expanded by a physicist, it is with my understanding that this is a sufficient knowledge base that an architect should have for office building design. This is because "mechanical engineers, by themselves, cannot achieve the desired level of performance without participation from architects and structural engineers" (Syed 2012).[22] The primary subjects of thermal comfort within a building are best represented by Figure 7.

Energy Use Reduction

This project will define building façade design strategies for harboring the effects of varying climate conditions to reduce energy use while promoting occupant comfort and views. This subject is also known as "regionally designing for energy conservation which aims to minimize the use of conventionally powered heating, cooling and lighting by supplementing natural energy available at the building site" (Bassler et al. 2000).[23] With respect to the low-rise modern open office building, "conduction, radiation, convection and vapor transfer are typically managed by building systems that require electricity and the intention is to work with the environment whenever possible, rather than against it to reduce this" (Bassler et al. 2000).[24]

Minimizing energy consumption related to passive design strategies will lessen the office building's utility costs and its dependency on natural resources. This is because electricity is the sole source of energy used for building systems and it is the byproduct

[22] Syed, *Advanced Building Technologies*, 115.
[23] Bruce Bassler, and John Hoke Jr., *Architectural Graphics Standard: An Abridgement of the Ninth Edition; Student Edition*, (New York: Wiley, 2000), 416.
[24] Bruce Bassler, and John Hoke Jr., *Architectural Graphics Standard: An Abridgement of the Ninth Edition; Student Edition*, (New York: Wiley, 2000), 416.

from burning fuel-oil at power plants which then transmit it. "There is a two-fold relation though, the amount of energy used for occupants and systems whereby actions and behaviors of the building users contribute to almost 50% of the overall energy consumption in a building" (Syed 2012).[25]

As part of this project, the objective will be to quantify electricity costs for the nearby region and commercial sector while understanding that future outlooks are only an approximation. After the combined passive design strategy has been chosen, recalculation of energy use reduction in regard to the proposed retrofit can take place. Accordingly, one can document the amount of energy that is reduced in regard to a recommended design strategy, thus proving its efficiency over a period of time. Energy cost reduction will become a component in comparing whether or not each of the retrofit design strategies are feasible using the simple payback period method based on the initial investment versus energy cost savings. This method of energy cost savings analysis, amongst more calculated versions, is used by the United States Department of Energy, National Renewable Energy Laboratory and is considered to be an “over-estimation of the actual payback period” (Eiffert et al. 2000).[26]

Like all other energy efficiency measures, they are not individual considerations. All are part of a much larger understanding and should be looked at together with respect to the users and their environment. The proposed passive design typologies discussed in this research project revolve around this concept. The comprehensive study of thermal

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[25] Syed, *Advanced Building Technologies*, 15.
[26]Patrina Eiffert and Arlene Thompson. United States Department of Energy: National Renewable Energy Laboratory, "U.S. Guidelines for the Economic Analysis of Building-Integrated Photovoltaic Power Systems," last modified February, 2000.

comfort, climate and building typology offers the capacity to triangulate the most effective solution whereby conserving energy and maintaining occupant comfort is key. This research project is therefore particular to the building façade in effort to target the primary scope for a feasible, yet comprehensive passive design retrofit for MLOOB envelopes. Accordingly, "a high performance building envelope is defined as performing better than mandatory energy code requirements by consuming less energy" (Syed 2012).[27]

The basis for energy cost savings reduction will compare differences of incorporating a hypothetical retrofit to an actual existing MLOOB (as-is) that is typical in the New York Metro Area. This process will occur in the design phase of this research project and will be expanded upon later. The proposed retrofit, which I hypothesize should have been included in the first place, can be compared with this baseline. The difference between the two is the energy savings and will therefore amount to an estimated cost. This estimate will then be compared to the retrofit cost estimate for construction. The costs for design fees, purchasing equipment, a contractor's installation and temporary protection will be considered. The passive design strategy retrofit cost can then be compared to energy cost savings to establish a simple payback period discussed earlier. By using current and projected utility costs for the New York Metro area one can more accurately estimate cost savings for this region. Additionally, these values will be expanded upon by discussing improvements to a building's carbon footprint. The footprint for an office building is considered to be "a measure of carbon dioxide (CO_2), methane (CH_4), nitric oxide (N_2O), hydrofluorocarbon (HFC), perfluorocarbon (PFC),

[27] Syed, *Advanced Building Technologies*, 117.

sulfur hexafluoride (SF_6) whereby CO_2 is measured in tons released into the atmosphere and the remaining gases are calculated as an equivalent baseline to it" (Syed, 2012).[28]

Carbon footprint reduction will be further emphasized in the design phase of this research project as it relies upon energy use reduction information to quantify tons of CO_2 annually diverted with respect to the proposed retrofit. United States Energy Information Administration (USEIA) conversion rates will be used for calculating these improvements over the existing office building as a baseline and will be discussed further in the design phase of this research project.

[28] Ibid.

Climate Data

pp 14-24

La Guardia Airport and New York Metro Area

Using climate data for building design promotes advantages for reducing energy use. As an important variable, "it influences external thermal loads of a project and is a gift of free energy of different forms and quantities when correctly used" (Hootman 2013).[29] While this research aims to generalize climate data for the New York Metro area, the representative climate station that will be studied is located at LaGuardia Airport, New York. This primary local climatological data site (LCDS) is one of six in the tri-state metro area of New York, New Jersey and Connecticut and is considered centrally located within this region by the author.[30]

Heating and Cooling Degree Days

By use of the average daily outside air temperature “T_o” one can attribute the respective amount of degree days which is equal to a 65°F baseline minus T_o. The 65°F is a neutral baseline that corresponds to interior heating or cooling requirements. An outdoor average temperature either above or below this constitutes degree days, in the amount and type of the difference. Accordingly, a positive number correlates to a daily amount of heating degree days (HDD) and vice versa. The reason one designs by using the average temperature of a 24 hour day is for meeting energy demands during the winter.[31] Respectively, HDD’s and cooling degree days (CDD) are made available by governmental weather data and can also be calculated.

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[29] Hootman, *Net Zero Energy Design*, 133.
[30] "Multiple-year Wind Roses from NYSDEC Monitoring Sites and NWS Sites," New York State Department of Environmental Conservation and National Weather Service, last modified April 21, 2011.
[31] "Monthly Cooling and Heating Degree Day Data," New York State Energy Research and Development Authority, last modified April 20th, 2012.

Example 1: If March 15th had a max temperature of 60°F and minimum temperature of 45°F (based on a 24 hour period) one should find the average between these temperatures (52.5°F), then subtract this number from the baseline temperature (65°F) and obtain 12.5 HDD.

In mathematical form, this is written as;

<u>Equation 2:</u> $HDD = 65 - \{ (Tmax - Tmin)/ 2 \}$ (Capehart et al. 2008)[32]

If we add all of the respective HDD values we can come up with an annual amount of HDD's for a given year. This same method of calculation also works for determining CDD. The charts in Table 1 are helpful in estimating energy usage for the future and can be used to forecast electricity costs for an office building. While this information has been averaged for each month, it should be mentioned that a study from 7:00am-6:00pm

Table 1: Heating and Cooling Degree Days

Source: National Oceanic and Atmospheric Administration, 2011.

Heating Degree Day

	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	Normal
January	0	1021	988	1114	848	806	722	1056	1213	1137	754	1008
February		794	871	780	810	981	786	815	839	995	668	861
March		714	520	713	683	682	645	810	672	700	637	713
April		354	219	360	321	421	264	321	355	470	338	392
May		114	82	111	148	75	95	204	80	203	161	136
June		4	0	27	0	3	11	10	11	41	20	16
July		0	0	0	0	0	0	1	0	0	0	1
August		0	0	0	0	6	0	0	0	0	1	1
September		19	0	23	15	5	12	5	11	11	6	40
October		223	163	256	252	91	213	194	230	263	297	249
November		383	461	395	547	530	342	413	474	422	555	524
December		662	923	868	802	808	600	878	829	806	871	836
TOTAL		4288	4227	4647	4426	4408	3690	4707	4714	5048	4308	4777

Cooling Degree Day

	2012	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	Normal
January	0	0	0	0	0	0	0	0	0	0	0	0
February		0	0	0	0	0	0	0	0	0	0	0
March		0	0	0	0	0	0	0	0	0	0	0
April		1	13	31	5	10	6	6	0	7	59	6
May		72	124	51	30	129	67	17	75	9	44	54
June		239	337	131	325	276	267	304	242	168	253	209
July		486	557	301	470	401	492	424	343	387	458	377
August		346	428	403	318	385	414	500	326	412	425	336
September		195	232	117	184	251	137	304	186	160	200	141
October		24	21	7	14	114	31	42	8	5	39	17
November		0	0	0	0	0	0	0	0	7	0	1
December		0	0	0	0	0	0	0	0	0	0	0
TOTAL		1363	1712	1041	1346	1566	1414	1597	1180	1155	1478	1141

[32] Barney Capehart, Wayne Turner, and William Kennedy, *Guide to Energy Management: Sixth Edition*, (Lilburn, GA: The Fairmont Press, 2008), 66.

would be more relevant as this is being considered a typical workday. This method will be used at a later stage, during the design phase of this project. Based upon this and other climate information, the modern low-rise open office building in the New York Metro area can be said to encounter varying weather conditions. Temperature fluctuations of nearly 60 °F between seasons are not uncommon. According to the climate data shown in Table 1, the average amount of HDD and CDD per year at LaGuardia Airport are 4,777 and 1,141 respectively. This information is based on a 30 year average, between 1971 and 2000, and shows more than a fourfold difference between the requirements for heating versus the smaller requirement of cooling. This is a concern for this design project as future design research suggests it is a challenge to accommodate this measure while maintaining occupant views and increasing daylighting.

Temperature Records

According to Table 2, there are five months where average temperatures are within the range of 62 ^{o}F – 76.5 ^{o}F. Temperatures within this range suggest that passive design strategies may be independently used to save energy. Highlighted months are the

Table 2: New York City Temperature Records (°F): Corrected Averages 10/02/11

Source: National Oceanic and Atmospheric Administration.

Month	Average Max (F)	Average Min (F)	Monthly Average	Coldest Average	Warmest Average
Jan	38.3	26.9	32.6	21.7 (1918)	43.2 (1932)
Feb	41.6	28.9	35.3	19.9 (1934)	40.6 (1998)
Mar	49.7	35.2	42.5	30.0 (1888)	51.1 (1945)
Apr	61.2	44.8	53.0	41.1 (1874)	57.9 (2010)
May	70.8	54.0	62.4	54.3 (1917)	68.7 (1991)
Jun	79.3	63.6	71.5	64.2 (1903)	76.2 (1943)
Jul	84.1	68.8	76.5	70.7 (1888)	81.4 (1999)
Aug	82.6	67.8	75.2	68.5 (1927)	80.3 (1980)
Sep	75.2	60.8	68.0	60.8 (1871)	73.5 (1961)
Oct	63.8	50.0	56.9	48.6 (1888)	63.6 (1947)
Nov	53.8	41.6	47.7	37.0 (1873)	52.7 (2001)
Dec	43.0	32.0	37.5	24.9 (1876)	44.1 (2001)
Year	**62.0**	**47.9**	**54.9**	**49.3 (1888)**	**57.2 (1998)**

UPDATED: Nov 26, 2011 Averages are based on the 30year period 1981-2010 basis for where research of climate data began. These months, in particular, indicate average temperatures that are acceptable and within the *summer passive zone* (SPZ) as identified in Figure 8. When researching further, one finds that April and October also share multiple days where there are maximum temperatures above 62°F. Based on 2011 temperature data for Central Park NY, April had 13 days where a max temperature was above 62 °F and October had 18 days making up almost half the amount of days for each month.[33] This shows that there may be a possibility of 180 days, or approximately half the calendar year, where passive design strategies may easily be used independent of active air conditioning to conserve energy use. Now that this information is on hand, it is fair to label passive design strategies as a substantial opportunity for the modern low-rise open office building located in the New York Metro area.

In order to focus climate information with respect of the primary use of a space, the start and end of a work day is an important factor. For the sake of simplicity, the commercial office building shall be studied during the duration of sunrise to sunset, throughout the calendar year. This is an ideal scenario as most passive design strategies are based on the sun being out and when the building is occupied. Since the office workday is generally from 7:00am to 6:00pm, this timeframe will be studied. With these prescriptions in place, the Mean Hourly Temperature Graph (Figure 8) indicates the most probable climate timeline of using passive design strategies to passively moderate the cooling of a space, based on mean outdoor air temperatures.

[33] "Temperature Records: Normals and Extremes Central Park, New York," National Oceanic and Atmospheric Administration, last modified November 26, 2011, http://www.erh.noaa.gov/okx/climate/records/nycnormals.htm.

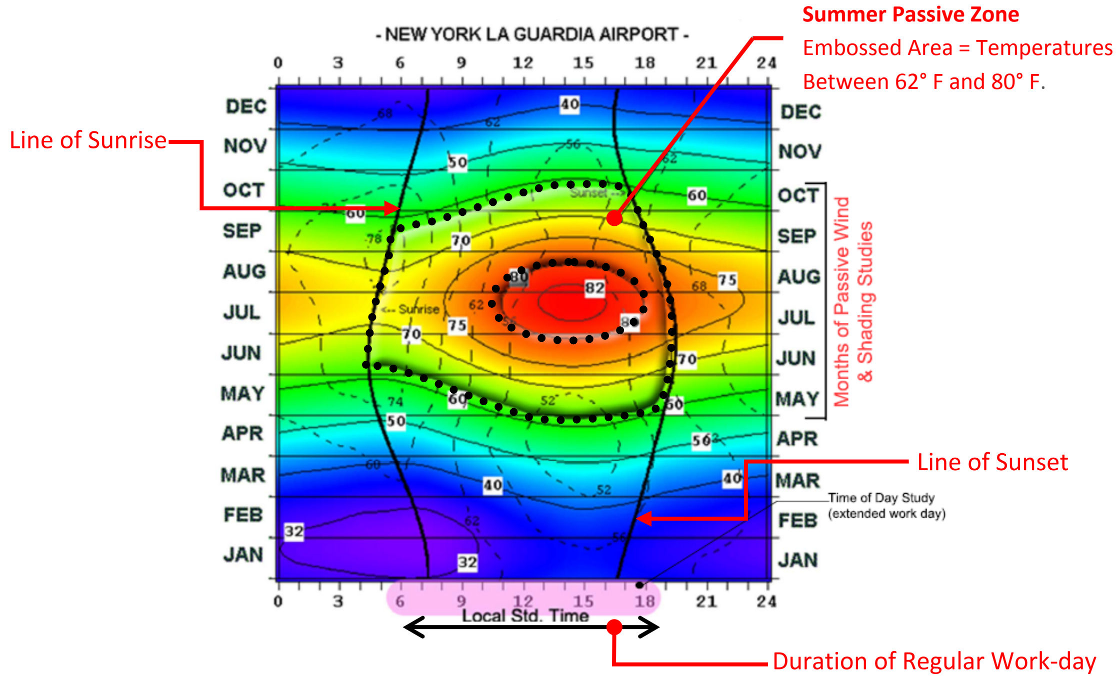


Figure 8: Mean Hourly Temperatures (Color and Solid Contours) and Relative Humidity (Dashed Contours)
Source: National Oceanic and Atmospheric Administration.

Areas contained within the two dotted boundaries of Figure 8 indicate the SPZ. It is constrained within the lines of sunrise and sunset as daylighting, solar radiation, natural ventilation and shading strategies can be used to moderate indoor air temperatures during this time. The temperature range as shown is conservatively between 62°F and 80°F for thermal comfort reasons presented earlier. It is based upon the variability of one's capacity to manipulate the "real feel" of temperature within an office and takes air speed, plus clothing insulation factors into consideration. We can see that the time of sunrise and sunset varies throughout the year and the SPZ is within a 6 month window. Specifically, this is where passive wind, daylighting and shading studies may take place to cool the office interior during warmer periods. Also noticeable is the average relative humidity percentages shown as dashed contours. To make this information easier to interpret, Figure 9 shows normal RH percentages for La Guardia Airport, NY during mornings and afternoons of each month.[34] Highlighted percentages represent values that are close to the ideal humidity level recommended by ASHRAE (less than 60%).[35]

JAN		FEB		MAR		APR		MAY		JUN	
M	A	M	A	M	A	M	A	M	A	M	A
67	58	65	55	67	53	67	51	71	53	72	54
JUL		**AUG**		**SEP**		**OCT**		**NOV**		**DEC**	
M	A	M	A	M	A	M	A	M	A	M	A
72	53	75	55	76	57	74	55	71	58	68	59

Figure 9: Annual Relative Humidity (%) Normals for La Guardia Airport, NY During Mornings (M) and Afternoons
Highlighted Numbers Represent near 60% relative humidity as Ideal.
Source: Dellinger 2008. Table created by Author.

[34] Dan Dellinger, "Average Relative Humidity (%)," National Climate Data Center, last modified August 20th, 2008. http://www.ncdc.noaa.gov/oa/climate/online/ccd/avgrh.html.
[35] "ANSI/ASHRAE Standard 55-2004" ASHRAE Inc., last modified 2004.

Wind Data

In respect to wind and how it could be used, the climate information of prevailing wind directions and mean wind speed analysis will help. At this point, this information shall only serve to be useful based upon proving wind will flow in all directions and that the average wind speed is more than 1.63 knots (1.8mph). This is the amount of wind required to offset the use of a thermostat by nearly 6 °F in an office environment on a warmer day. The graphs in Figure 10 confirm this information. The mean wind speed graph also suggests that during warmer periods of the year, from sunrise to sunset, higher wind-speeds are more readily available.

Left: Arrows represent prevailing wind directions based on an 8-point compass at 15 knots. Frequencies are indicated by intensity of colors and contours. **Right:** Mean wind speeds are annually represented by contours for 24 hour periods. **Note:** Dark black lines indicate sunrise and sunset based on the time of day for both images and varies as shown.

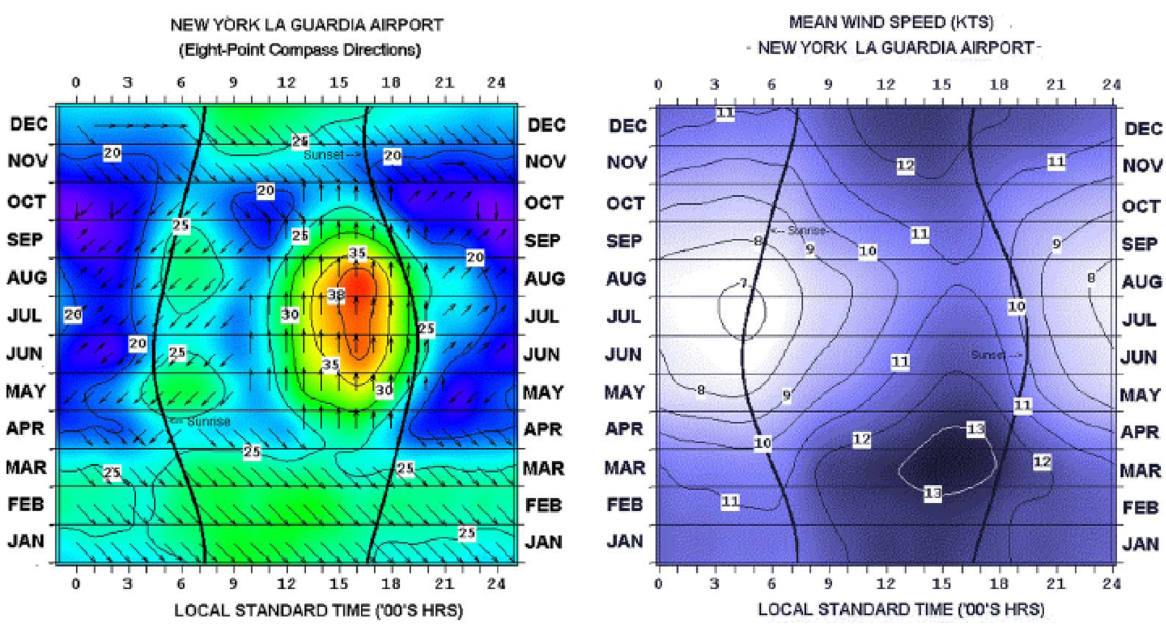


Figure 10: Prevailing Wind Directions, Mean Wind Speeds and Frequencies for New York La Guardia Airport
Source: National Oceanic and Atmospheric Administration.

Opening percentages and locations of windows can manipulate how much wind enters a space at a given time of day. Therefore, window operability is important on all sides of the office building in the New York Metro area when this option is on hand.

Going back to Figure 9, the remaining area outside of the SPZ is where daylighting and solar radiation studies may prove more useful than prevailing wind information shown in Figure 10. This is true so long as the office interior requires heating, making wind speeds and wind directions less useful.

Solar Exposures

While natural ventilation may be less useful during these cooler periods, daylighting and solar insolation factors can thankfully be used to an advantage. In regard to climate data for solar exposure, sun path and unobstructed sky, Figure 11 is helpful.

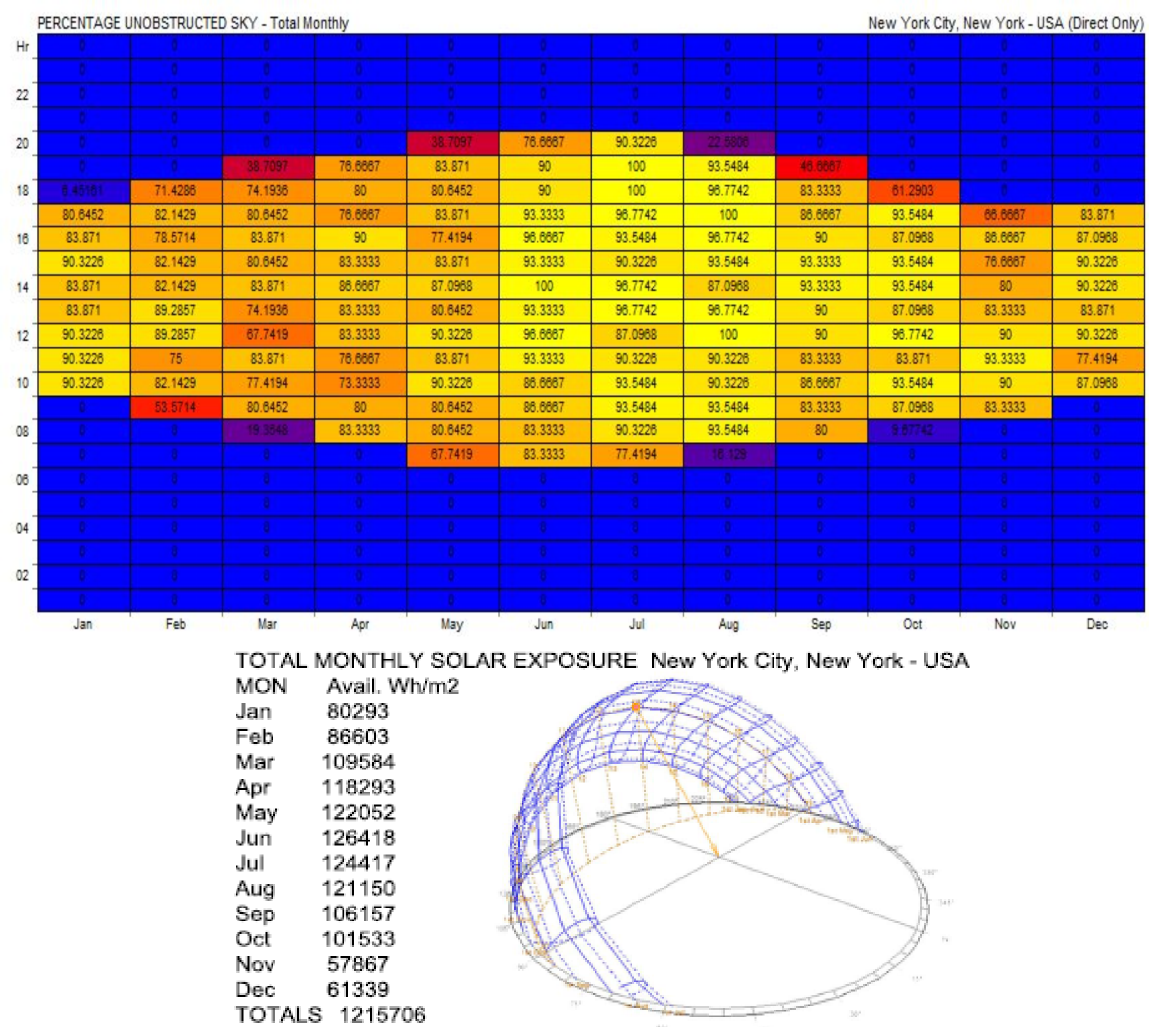
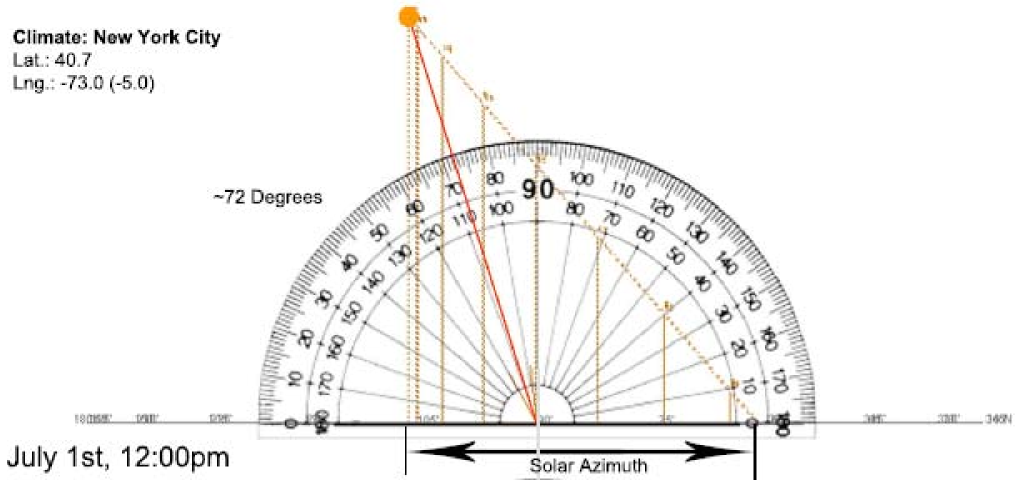


Figure 11: Total Monthly Solar Exposure and Percentage of Unobstructed Sky for New York City, New York.
Source: Autodesk Ecotect Analysis 2011.

This compiled set of information shows average intervals of each month. In other words, these data may be helpful to provide solar exposure information in $\mathrm{W/m^2}$ for the office interior at any hour of the workday. It also indicates when and where shading devices could be used and that cloudy skies decrease towards the middle of the day. Lastly, one can comfortably say that available solar radiation measurably decreases during the winter along with the sun's angle. Also, cloudy skies are more common.

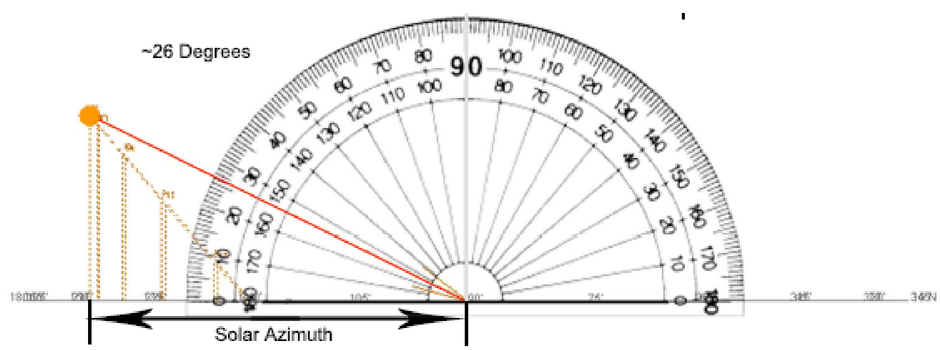
Sun angle comparisons between seasons can be seen in Figure 12. This information, in addition to the sun path for the New York Metro area is based upon the latitude of 40.7° and longitude of -73.0° and has been derived from Autodesk Ecotect Analysis 2011. Accordingly, it will help determine shading and daylighting criteria throughout the year and will undergo further review in the design phase of this project.



July 1st, 12:00pm

Equation of Time (minutes):	Solar Declination (degrees):	Solar Azimuth:	Solar Elevation:	cosine of solar zenith angle
-3.99	23.04	183.04	72.32	0.9527

Azimuth is measured in degrees clockwise from north.
Elevation is measured in degrees up from the horizon.



January 1st, 12:00pm

Equation of Time (minutes):	Solar Declination (degrees):	Solar Azimuth:	Solar Elevation:	cosine of solar zenith angle
-3.42	-23.01	181.17	26.31	0.4433

Azimuth is measured in degrees clockwise from north.
Elevation is measured in degrees up from the horizon.

Note: Angle of Incidence Varies Between 26 and 72 Degrees Based on Date and Time of Day

Solar Angle Source: Autodesk Ecotect Analysis 2011
Weather File: USA-NewYorkNewYork.wea

Figure 12: Average Sun Angle on July 1st Versus January 1st at 12:00pm for New York City, NY
Source: Autodesk Ecotect Analysis 2011.
National Oceanic and Atmospheric Administration Solar Position Calculator, http://www.esrl.noaa.gov/gmd/grad/solcalc/azel.html, Accessed March 5th, 2013.

Current and Projected Electricity Prices

pp 25-29

Commercial Sector:

By reference to Table 3; Commercial Sector Key Indicators and Consumption as prepared by the U.S. Energy Information Administration, national projections of energy use for the commercial sector are available from 2009 through 2035. This information is coded by end use, thereby narrowing the subjects of projected growth for electricity used in lighting, ventilating and space heating/ cooling and can be considered a very bold prediction.

Table 3: Commercial Sector Key Indicators and Consumption in Quadrillion Btu Per Year
Source: United States Energy Information Administration,
Annual Energy Outlook, 2012 Early Release Table A5.

Key indicators and consumption	Reference case							Annual Growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Key indicators [1]Includes fuel consumption for district services.								
Total floorspace (billion square feet)								
Surviving	78.0	79.3	82.4	87.1	91.9	96.2	100.7	1.0%
New additions	2.3	1.8	1.7	2.1	2.0	2.0	2.3	1.0%
Total	**80.3**	**81.1**	**84.1**	**89.1**	**93.9**	**98.2**	**103.0**	**1.0%**
Energy consumption intensity (thousand Btu per square foot)								
Delivered energy consumption	106.0	107.3	105.0	103.2	101.3	101.2	100.3	-0.3%
Electricity related losses	117.0	117.3	111.2	111.7	112.3	111.9	111.1	-0.2%
Total energy consumption	223.0	224.6	216.2	214.9	213.6	213.1	211.4	-0.2%
Electricity related losses	**9.39**	**9.52**	**9.35**	**9.95**	**10.54**	**10.99**	**11.45**	**0.7%**
Total energy consumption by end use								
Space heating[1]	2.34	2.35	2.32	2.32	2.28	2.26	2.22	-0.2%
Space cooling[1]	1.49	1.76	1.56	1.57	1.59	1.61	1.62	-0.3%
Water heating[1]	0.75	0.75	0.78	0.80	0.82	0.83	0.83	0.4%
Ventilation	1.56	1.57	1.62	1.72	1.80	1.86	1.91	0.8%
Cooking	0.25	0.25	0.26	0.27	0.27	0.28	0.29	0.6%
Lighting	3.21	3.14	3.05	3.16	3.27	3.35	3.40	0.3%
Refrigeration	1.24	1.21	1.06	1.03	1.02	1.03	1.05	-0.5%
Office equipment (PC)	0.67	0.66	0.57	0.58	0.60	0.62	0.64	-0.1%
Office equipment (non-PC)	0.77	0.81	0.95	1.11	1.22	1.30	1.37	2.1%
Other uses[6]	5.62	5.72	6.01	6.58	7.19	7.78	8.46	1.6%
Total	**17.90**	**18.22**	**18.19**	**19.15**	**20.06**	**20.92**	**21.78**	**0.7%**

As derived from Table 3, commercial spaces are analyzed by their floor area in billions of square feet and are projected to increase by +1.0% annually. This implies that more than ten million square feet of commercial sector floor area may be added each year in the United States. Energy consumption, in thousand Btu per square foot, is expected to decrease by -0.2% annually. This suggests that although there may be an increase in floor area, there may also be a decrease in energy use per square foot of floor space (both existing and new) by two hundred thousand Btu per year.

Also with reference to Table 3, electricity related losses are expected to increase at an average of +0.7% each year. Additionally, electricity used for space heating and space cooling are projected to decrease annually at an average rate of -0.2% and -0.3%, respectively. Electricity used for ventilation and lighting is expected to increase annually at an average rate of +0.8% and +0.3%, respectively.

In summary of these three projections; as more energy is provided, there will be more energy loss through transmission. Also, while there will be a small decrease in energy use per year for space heating and cooling there is a larger projected increase in energy used for ventilation and lighting. Without going further into this, one may speculate that with the current trend of increasing energy efficiency for space heating and cooling equipment and displacing existing inefficient buildings with more efficient new buildings, this projection may be plausible. For the matter of increased floor areas, this will inevitably require more ventilation and lighting whereby energy efficiency measures may be exceeded by additional energy used per unit of floor area. These are important things for office building owners and designers to consider as there may be new energy conservation goals and code requirements to abide by in future years.

Region: New England Vs. Nation

When relating energy usage to utility costs for the New England region commercial sector, the United States Energy Information Administration (USEIA, 2012) short term versus projected long term outlook charts is useful. From Table 4, short term commercial electricity rates may increase through 2013, possibly to 14.59 cents per

Table 4: Short and Long Term Energy Prices by Sector and Source For New England Region in 2010 Dollars Per Million Btu
Source: United States Energy Information Administration, Annual Energy Outlook, 2012 Early Release Table 7c, 11.

	2011				2012				2013				Year		
	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	2011	2012	2013
New England	14.38	14.37	14.49	14.07	14.47	14.54	14.71	14.30	14.55	14.63	14.78	14.36	14.33	14.51	14.59
Middle Atlantic	13.23	13.76	14.52	13.10	12.89	13.67	14.60	13.14	13.12	13.90	14.86	13.37	13.68	13.61	13.85
E. N. Central	9.30	9.62	9.63	9.33	9.36	9.64	9.77	9.53	9.49	9.79	9.91	9.67	9.48	9.58	9.72
W. N. Central	7.60	8.47	8.96	7.80	7.59	8.45	9.02	7.86	7.73	8.61	9.18	8.01	8.23	8.26	8.41
S. Atlantic	9.40	9.51	9.62	9.53	9.45	9.57	9.79	9.69	9.47	9.59	9.80	9.70	9.52	9.63	9.65
E. S. Central	9.54	9.73	9.81	9.74	9.29	9.56	9.73	9.78	9.27	9.54	9.70	9.74	9.71	9.60	9.57
W. S. Central	8.55	8.65	8.90	8.49	8.70	8.82	8.94	8.59	8.97	9.07	9.20	8.84	8.67	8.77	9.03
Mountain	8.25	9.01	9.29	8.71	8.25	9.01	9.27	8.67	8.31	9.07	9.34	8.73	8.84	8.83	8.89
Pacific	10.89	12.29	13.71	11.46	10.77	12.10	13.62	11.52	10.65	11.98	13.48	11.40	12.14	12.05	11.94
U.S. Average	9.97	10.38	10.76	10.10	9.95	10.39	10.84	10.21	10.03	10.46	10.91	10.28	10.32	10.37	10.44

New England - 01

Sector and Source	2009	2010	2015	2020	2025	2030	2035	2010-2035
Commercial								
Liquefied Petroleum Gases	21.10	22.81	26.53	27.06	28.18	29.08	30.36	1.1%
Distillate Fuel Oil	16.49	20.86	25.38	26.96	28.42	29.87	31.28	1.6%
Residual Fuel	13.66	10.94	16.76	18.23	18.87	19.70	19.47	2.3%
Natural Gas	12.18	11.12	10.26	10.76	11.50	11.73	12.74	0.5%
Electricity	45.14	43.15	35.33	34.78	34.98	32.68	33.68	-1.0%

Note: The New England and Middle Atlantic regions are both part of the New York Metro area. Since peak energy use cost escalation factors for large scale commercial buildings is not being considered, higher rates between these two regions is used.

Table 5: National Energy Prices by Sector and Source in 2010 Dollars Per Million Btu
Source: United States Energy Information Administration, Annual Energy Outlook, 2012 Early Release Table A3.

Sector and source	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Commercial								
Liquefied petroleum gases	21.76	23.52	27.36	27.90	29.02	29.93	31.21	1.1%
Distillate fuel oil	16.16	20.77	23.87	25.39	26.87	28.31	29.52	1.4%
Residual fuel oil	13.66	11.07	16.11	17.58	18.23	19.04	18.86	2.2%
Natural gas	9.82	9.10	8.59	9.21	10.12	10.53	11.55	1.0%
Electricity	30.06	29.73	28.07	27.78	27.74	26.98	27.99	-0.2%

Kilowatt Hour (KWh). Comparing long term data, with reference to Table 4, commercial electricity prices are expected to decrease by about -1.0% each year. In comparison to the national long term projected data (Table 5) commercial electricity costs in the New England region are projected to have a larger decrease in price (-1.0% New England versus -0.2% nationally). While this is not the ideal scenario for promoting passive design strategies based on increasing utility costs alone, it should be mentioned that the cost of electricity is already considered to be very high by the New England Energy Alliance.[36] Combined with the idea of conserving natural resources and minimizing pollution there are other compounding effects that will be realized when minimizing energy usage.

Going forward, this set of information will be quantified based on the analysis of an existing symbolic modern low-rise open office building, including a proposed passive design strategy retrofit. This will take place during the design aspect of this research project which will use these data in order to formulate conclusions. The amount of 14.59 cents per Kilowatt hour (from Table 4) for year 2013 will be used for future simple payback period analysis.

[36] "A Review of Electricity Industry Restructuring in New England," New England Energy Alliance, October 26, 2006, http://www.hks.harvard.edu/hepg/Papers/NEEA_0906.pdf.

The Modern Low-rise Open Office Building Typology

pp 30-34

Process Statement:

In order to continue with this study in a methodological approach, this research intends to create a definition for the modern low-rise open office building which will be investigated further in the design phase of this project. To do this, one must separate each building design aspect individually and then recompose these characteristics to help the selection process for the typical office building. Once selected, it will undergo a proposed retrofit analysis and compared to the existing building as a baseline.

By Definition: Low-rise, Modern:

The term “low-rise” shall bring focus to a building six stories or less as there is no universally established height requirement. In establishing what a “modern” building is one must look to what the key features of modern architecture are. According to Theodore Prudon (2008), "modern architecture is inspired by a collective optimism and a sense of opportunity that embraces innovation and strives to use the achievements of the Industrial Revolution to provide aesthetic and social benefits through functional buildings for more and more people.[37] Another good source to validate what a modern building should be has been prepared by the Documentation and Conservation of the Modern Movement in the United States. As categorized by their definitions, “It must first be located upon a modern landscape” (Docomomo 2012).[38] For the purposes of this research, the suburb shall be considered a modern landscape. As urban centers expand creating adjacent communities, a suburb can then be looked at as the byproduct of a city. This is also known as the modern phenomenon called urban sprawl. For this reason, it is

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[37] Theodore Prudon, *Preservation of Modern Architecture*, (Hoboken: Wiley, 2008), 23.
[38] "How to Evaluate Modern Buildings and Sites," Documentation of the Modern Architecture Movement: New York, last modified 2012, http://www.docomomo-us.org/register/how_to_evaluate.

my belief that the suburb is a modern landscape as it responds to the urban context. Next, in order to further describe the term “modern” with respect to what the building should be, Docomomo US has described additional criteria. “A modern building is artistic and unique in looking forward and to the future, without having overt references to historical precedent. Modern design expresses functional, technical and spatial properties and attempts to solve structural, programmatic and aesthetic issues with simplicity, thereby creating an ornament. It also reflects the changing social patterns of the 20th century” (Docomomo, 2012).[39]

It is important to note this research will not determine what successful modern architecture is, rather it will use this information as a guide in selecting a typical office building to be studied. To be more specific, the chosen symbolic office building must lack the incorporation of basic passive design strategies in order for this research to be more effective. These principles are based upon passive design typologies that respond to the environment, particularly the subjects of wind, sun and air temperature. Lastly, this building should have an entirely glass and metal curtain-wall envelope system and be defined as new construction within the timeframe of 1970's to present, making it late-modern.

By Definition: Office, Open:

The term “office” can be identified as any building that fits within an appropriately zoned section, block and lot as identified by local authorities for the act of

[39] "How to Evaluate Modern Buildings and Sites," Documentation of the Modern Architecture Movement: New York, last modified 2012, http://www.docomomo-us.org/register/how_to_evaluate.

commerce. This information can be validated based on the placement of a building with respect to an official zoning map and permitted use of an office space. The subject of an “office building” varies, but is best categorized by the Whole Building Design Guide’s (WBDG) by what spaces it contains. According to the WBDG (2009), "a typical office space may include a lobby, office work spaces, integrated meeting spaces, core office support spaces; work rooms, storage rooms, file rooms, mail rooms, copy areas, telephone, mechanical and communication equipment rooms. Other spaces can include a convenience store, cafeteria, private toilets, child care, physical fitness, interior or surface parking."[40]

Combining this information with additional office building spaces that come to mind one can also mention elevator lounges, hallways, corridors, egress stairwells, delivery and receiving areas. All of these spaces represent the building core and help set the criteria for selecting the symbolic office building for the proposed retrofit. To minimize the subject matter and focus upon the primary target market whereby passive strategies may have the most impact, this research will regard open office typologies. "Such spaces can be identified as having 80% or more of the floor area as open" (WBDG 2009).[41] These spaces are considered to be “more flexible, cost-effective, energy efficient and aesthetically pleasing environments” (WBDG, 2009).[42] Also to add, it will place further emphasis on passive design strategies and how they can reduce energy usage at a more uniform and larger scale. It will minimize the study of temperature gradients between walls and floors and provide for a more precise analysis with simpler

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[40] "Office Overview," National Institute of Building Sciences: Whole Building Design Guide, last modified June 2, 2009, http://www.wbdg.org/design/office_st.php.
[41] Ibid.
[42] Ibid.

conclusions. This ultimately helps minimize complexity and is appropriate as the “open office typology is becoming increasingly more common” (Acitelli 2011).[43] This subject is reinforced by Patricia Roberts (2012) at Jones Lang LaSalle, a global commercial real estate firm. She mentions that, “…in general, cubicle sizes are getting smaller, the panel heights are getting lower and these environments are becoming more open. More and more people are thinking about open environments supported by closed spaces.”[44]

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[43] "Offices With More Breathing Room," The New York Times, December 13, 2011, http://www.nytimes.com/2011/12/14/realestate/commercial/in-manhattan-higher-ceilings-and-lots-of-light-attract-businesses.html.

[44] Acitelli 2011. "Offices With More Breathing Room," The New York Times, December 13, 2011.

Passive Design Strategies

pp 35-40

Basis of Study:

Passive design strategies relating to wind, sun and air will be studied based on conserving energy for the modern low-rise open office building. All of these climatic conditions are "heavily cinematic with the fourth dimension of architectural space; time" (Krishan et al. 2001).[45] This synergistic study is intended to move the architectural design, energy and facilities management professions towards a common goal. This is based on the subject of sustainable design "which is with place; a more profound matrix of building performance than programmatic or individual concerns" (Krishan et al. 2001).[46] The objective is to prove that one can achieve a higher standard of energy conservation without compromising the necessity of occupant comfort. As best referenced, "passive design is an approach to building design that uses the building architecture to minimize energy consumption and improve thermal and occupant comfort and can greatly reduce building energy requirements before mechanical systems are considered" (Cobalt Engineering 2008).[47]

It is important to note that while this study may be used for multiple building typologies, this approach is considered to be atypical. Building construction, site planning, space planning, orientation, construction materials and weather patterns vary at even the most micro levels which could directly affect the choice between design strategies. Therefore, this research shall only be used as an example and is not to be considered prescriptive by any means. As pointed out by Cobalt Engineering and Hughes Condon Marler Architects (2008) in preparing a study for the City of Vancouver,

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[45] Arvind Krishan, Nick Baker, Simos Yannas, and S V Szokolay, *Climate Responsive Architecture: A Design Handbook for Energy Efficient Buildings*, (New Delhi: McGraw Hill, 2001), 4-6.
[46] Ibid., vii.
[47] "Passive Design Toolkit: Best Practices," Cobalt Engineering, and Hughes Condon Marler Architects, last modified 2008, http://vancouver.ca/sustainability/documents/PassiveDesignToolKit.pdf.

“modeling results are useful and valid, but do not replace the value of project-specific studies.”[48] As summarized in their study, the following passive design strategies are believed to pertain to a building retrofit project. While Vancouver is quite a bit away from the New York Metro Area, it goes to mention that the strategies are similar. As recommended, a building designer should:

"-Design each façade specific to its orientation.

-Minimize East and West exposures to minimize solar gains.

-Use an air tight envelope to minimize uncontrolled infiltration.

-Use either clear glass with effective external shading elements or dark reflective glass. Both of which should be Low-e, having good insulating value.

-Incorporate overhangs and operable external shading on East, South, and West facing windows.

-Design for cooling by use of natural ventilation.

-Optimize the effects of passive heating and cooling strategies by strategically combining passive elements" (Cobalt Engineering et al. 2008).[49]

In the process of selecting the most appropriate passive design strategy one should first define the terms of thermal comfort and study the climate of where the building is located. Both steps have already been conducted in this research and promote intuitiveness and factual data that can be used to formulate strategies. This goes hand in hand with the recommendation to “understand and establish clear, realistic and

[48] "Passive Design Toolkit: Best Practices," Cobalt Engineering, and Hughes Condon Marler Architects, last modified 2008, http://vancouver.ca/sustainability/documents/PassiveDesignToolKit.pdf.
[49] Ibid.

measurable energy performance targets" (Cobalt Engineering et al. 2008).[50] Also, as documented, by combining passive design strategies one can achieve compounding effects of energy savings in addition to reduced costs relevant to initial investments.[51] This is possible in the sense where a light-shelf may doubly function as a shading device. During the summer it could afford deflection of solar radiation and in the winter could afford daylighting and needed heat gain if located and used properly on a building façade. It should also be mentioned that on the contrary, "by combining strategies that do not help one another, or using them in isolation one could amount to a negative outcome" (Cobalt Engineering et al. 2008).[52] For instance, where one would appreciate solar radiation on an east or west oriented curtain wall, they would also have to depreciate it during summer months with the use of shading devices to control heat gains. For the open office interior this is critical as most of the perimeter building floor areas share the same space.

Since energy loss is attributed to the building envelope as a whole, it should be mentioned that the roof and floor slab are also important with regard to heat loss and heat gain. When not being used for renewable energy, the office building roof in the New York Metro area should idealistically be designed to absorb solar radiation during colder periods and insulate the office interior during warmer periods. The issue is that it is very difficult to accomplish both design strategies for an existing building, without going against each other and becoming expensive for a passive design retrofit of an MLOOB envelope.

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[50] Ibid.
[51] Krishan, Baker, Yannas, and Szokolay, *Climate Responsive Architecture*, 43-52.
[52] "Passive Design Toolkit: Best Practices," Cobalt Engineering, and Hughes Condon Marler Architects, last modified 2008, http://vancouver.ca/sustainability/documents/PassiveDesignToolKit.pdf.

Daylighting and natural ventilation modifications to an existing roof can also be considered difficult since the adjustments may only be useful for the upper floor levels unless openings are punched through the reinforced concrete floor slabs or masonry core fire-walls (to bring them down and through). For existing buildings, this can be considered a substantial modification for minimal improvement. Since the roof is intended to provide the function of a shelter; offering shade, temperature moderation, as well as protection from snow and water, focus will remain on solar radiation. This can be especially said for the MLOOB which typically has a flat roof. In this instance, solar radiation can either be reduced or increased on this horizontal plane by manipulating a surface materials' solar reflectivity index (SRI) in addition to roof cavity materials. Insulating cavity materials may include the structure, batt or rigid insulation, the waterproofing membrane and other smaller components. All of which should ideally encapsulate each other at all four edges to minimize air convection between materials due to voids.[53]

As discussed earlier, the amount of heating degree days for the New York Metro area is, on average, more than four times than cooling degree days. This suggests a darker and rougher surface material may be more appropriate. In this case, one would think the lower SRI value is more ideal as it is closer towards black. This scenario intends to warm the office interior during cooler periods which are experienced for longer durations of the year. While this is the case, we do not want to minimize our efforts for maintaining building envelope waterproofing and incorporating passive design strategies that aim to cool the office in the summer. According to William Allen (1997), "a dark surface in a

[53] Adrian Tuluca, *Energy Efficient Design and Construction for Commercial Buildings*, (New York: McGraw Hill, 1997), 6.

temperate climate naturally increases solar warming of the roof slab which misbehaves by enlargement and more complexly by swinging around and arching at anchorage points of the roof structure."[54] For these reasons the suggestion of a light color, well insulated and ventilated roof that has the capacity to act as a thermal mass would be the ideal scenario for the MLOOB roof in the New York Metro area. This understanding directly correlates to Arvind Krishan's et al. (2001) theoretical discussion of specific heat where he states "…each material has one and when it comes to specific heat exchanges we are concerned with this as well as the amount of mass a material has."[55] Based on the laws of thermodynamics, heat flows from hot to cold and during the majority of the year we should make an effort to balance this.

Since economics partly guides decision-making; it should be mentioned that in the case of a poorly insulated roof that additional insulation may be proposed as part of the retrofit project. This is rather than other substantial roof cavity or surface material modifications that may be unpractical. Without looking to the landscape and site for solutions, the analysis of existing passive design strategies including solar radiation and shading for the common MLOOB is relevant. The criteria for studying existing passive design strategies must be suitable for glass curtain wall systems that make up a majority of the building facade.

[54] William Allen, *Envelope Design for Buildings*, (Boston: Architectural Press, 1997), 189.
[55] Krishan, Nick Baker, Simos Yannas, and S. V. Szokolay, *Climate Responsive Architecture*, 45.

Solar Radiation, Shading, Daylighting and Views

pp 41-62

Concepts:

The term solar radiation is also known as radiative heat gain or solar heating. This is a very important consideration when promoting passive design strategies "as a surface can become heated thereby warming air and other surfaces" (Krishan et al. 2001).[56] For the modern low-rise open office building this subject is compounded by ample glazing which in some cases extends to more than 90% of the façade area. Some of the glazing may be spandrel, clerestory, or viewing components of a larger curtain wall system. Depending upon surface textures, colors and opacities; "incident radiation can be absorbed, reflected or stored and reradiated later" (Krishan et al. 2001).[57] The question then becomes whether one should absorb it, or deflect it based on the time of day, year, occupancy criteria and weather conditions.

Part of the answer for the New York Metro area modern low-rise open office building is that one should make every attempt to absorb solar radiation when there are heating degree days. The data gathered from climate analysis provides the necessary information to design a retrofit project in a certain manner. For instance, solar radiation is averaged at its highest level on July 1st, whereby more than 840 w/m^2 per hour will arrive at an approximate angle of incidence of 72° (based on Figure 13). Subtract this angle from 90° (vertical) and this creates an 18° angle. This solution could then be used to determine the minimum depth of a horizontal shading device. Start from the lowest extent which is in need of shading and project the 18° angle counterclockwise from vertical towards the exterior. The triangle this creates can then be used with the mathematical order of tangents to determine the depth (Equation 3). This methodology holds true for

[56] Krishan, Baker, Yannas, and Szokolay, *Climate Responsive Architecture*, 57-62.
[57] Ibid., 11.

the New York Metro area and can be used for any low-rise open office building. The reference point is taken from a horizontal plane whereby a vertical curtain wall can be considered linear and is oriented perpendicular to the south compass direction.

The same methodology holds true for the maximum depth of a horizontal shading device. First, find the lowest sun angle of the year which solar radiation should be blocked. This will offer additional shading device criteria and therefore the most suitable depth. It can also be found by referencing the climate data as shown in Figure 13. This figure illustrates that a portion of May through the beginning of October are months which solar radiation should be blocked. As depicted, minimizing radiative heat gain is especially important for the months of June through September where average outdoor temperatures reach well above 74 °F. For this matter, one should look at the approximate start date where solar radiation becomes a thermal comfort issue and then use the solar angle on this date. For instance, Figure 13 illustrates that at approximately 2:15pm on June 6th all the way through September 10th at 2:15pm outdoor temperatures are above 74 °F. By comparing solar angles for both dates at 2:15pm, one should select the lower sun angle to determine the best horizontal projection from the building façade. In this case, as Figure 13 indicates September 10th as having a more obtuse angle (counterclockwise from vertical) in comparison with the same time on June 6th. This angle is approximately 36° from vertical.

By using the previously explained methodology one would again solve for ‘x’ in Equation 3. For purposes of simplicity, the following example has been provided using this information as a reference case. Since solar angle/radiation information minimally changes along near equal latitudes around the New York Metro area, this finding may be

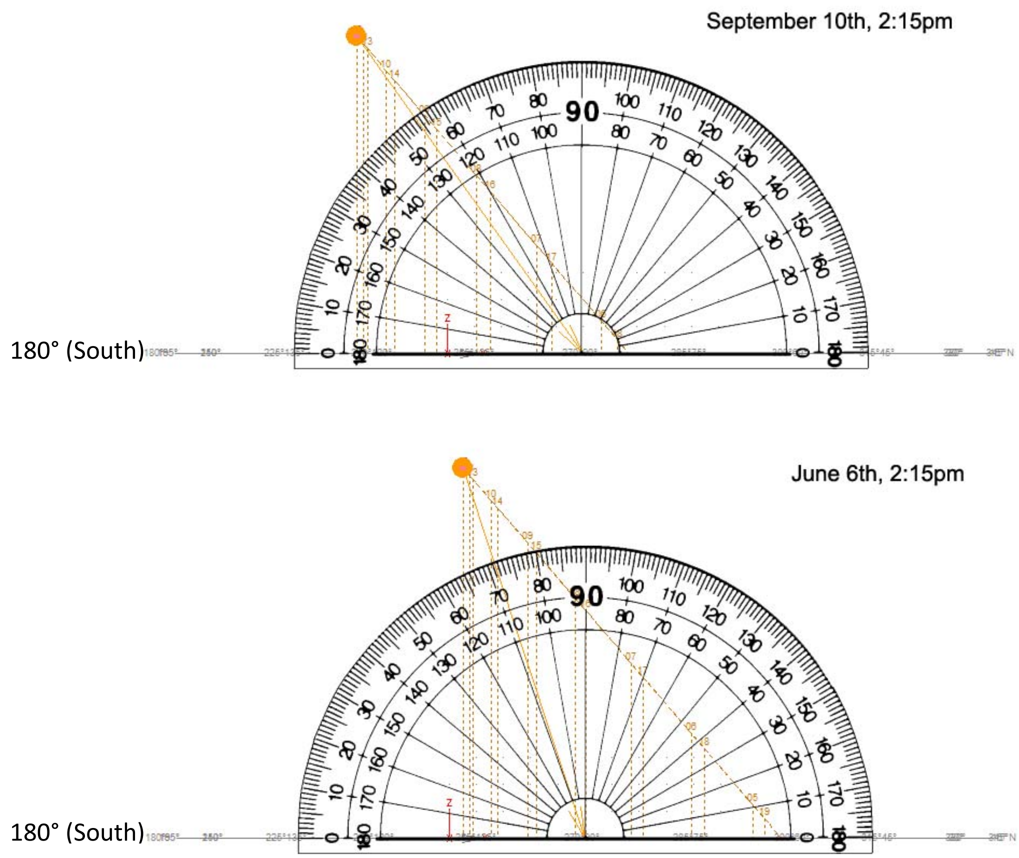

Figure 13: Comparison of Sun Angles for June 6th and September 10th at 2:15pm
Source: Autodesk Ecotect Analysis 2011, United States Department of Energy
Weather File for New York City, NY.

used for any low-rise open office building with a south facing orientation.

Example 2: Office Building Requires Exterior Shading Device for Passive Cooling.

Assuming a south facing curtain wall glass façade (perpendicular to south compass direction) with a 5' high viewing window requires full shade; the appropriate horizontal depth for a shading device **'x'** can be determined using the lowest sun angle when peak solar radiation is an issue. The objective would be to minimize solar radiation which would otherwise enter through the viewing window glazing and therefore the office interior.

Determining the Horizontal Projection Dimension of a Shading Device 'x':

Equation 3:

Tan (Sun angle degrees from vertical) = **x** / (5 ft. x 12 in./ft.)

Tan (36°)=x/(60in.), solving for x: 43.59 inches

Using the data previously described one can begin to solve the equation for **x**. Since the viewing window height is converted into inches, and the sun angle is 36° from vertical; one finds that "**x**" equals 43.59 inches. Therefore, the horizontal projection from the top extent of the viewing window should be about 44 inches in order to fully shade the viewing window glazing during the lowest sun angle event that solar radiation may negatively affect thermal comfort. If we are to split the window up into two equal vertical segments, then this shading device may be half the size.

On the other hand, increased solar radiation during the winter is not a concern. In fact, the building should welcome as much solar radiation as possible. This is why shading devices are less important and light shelves (projected horizontal reflective surfaces) are more useful. Respectful of previous studies, one can again look to the climate data to find the duration that solar radiation should be absorbed. In respect to mean hourly temperatures (Figure 8) the ideal date/ time to welcome solar radiation is from January to June and from parts of October through December. In other words; this duration is where the mean annual temperature range drops below 62 °F. This means that clear glass windows with low-e coatings are suitable so long as they are appropriately shaded when the interior temperature increases above the recommended level of thermal comfort. This type of coating "has the ability to minimize harmful ultraviolet rays; in some cases by 98%" (Murray 2009).[58] Therefore, a conclusion can be made that during select winter, spring and fall months; increased solar radiation is necessary and should not be blocked. This information also coincides with the best horizontal projection dimension as described earlier.

Although this is useful in determining the most ideal solar angle based on average outdoor temperatures and sun path, it is then logical to question how the shading device should respond to a day, month, or a year that may be abnormally cold or warm. The solution here could be an operable shading device that has the possibility to extend and retract as required. Feasibility and costs become the issue when thinking along this respect though, especially for a retrofit project. For this reason, fixed scenarios will be discussed alongside operable design strategies. Careful consideration must be made as to how something like this could be feasible.

Basic Typologies:

Common shading typologies aimed at reducing heat gains can be seen in Figure 14. These typologies have been gathered from multiple sources and then redrawn for clarity. Accompanying each prototype shown in perspective is a plan or section view of what each may look like in its simple form. Accordingly, outdoor viewing capacities of building occupants are either maintained or reduced based on the viewing plane obstructions due to each of the shading types. They have appropriately been labeled with measurement fields ranging from zero percent (lowest) to 100% (highest) indicating the amount of visibility from indoor to outdoor. This indication has been prepared with the common assumption of sunlight and viewing occurring in multiple directions. The

[58] Murray, *Contemporary Curtain Wall*, 75.

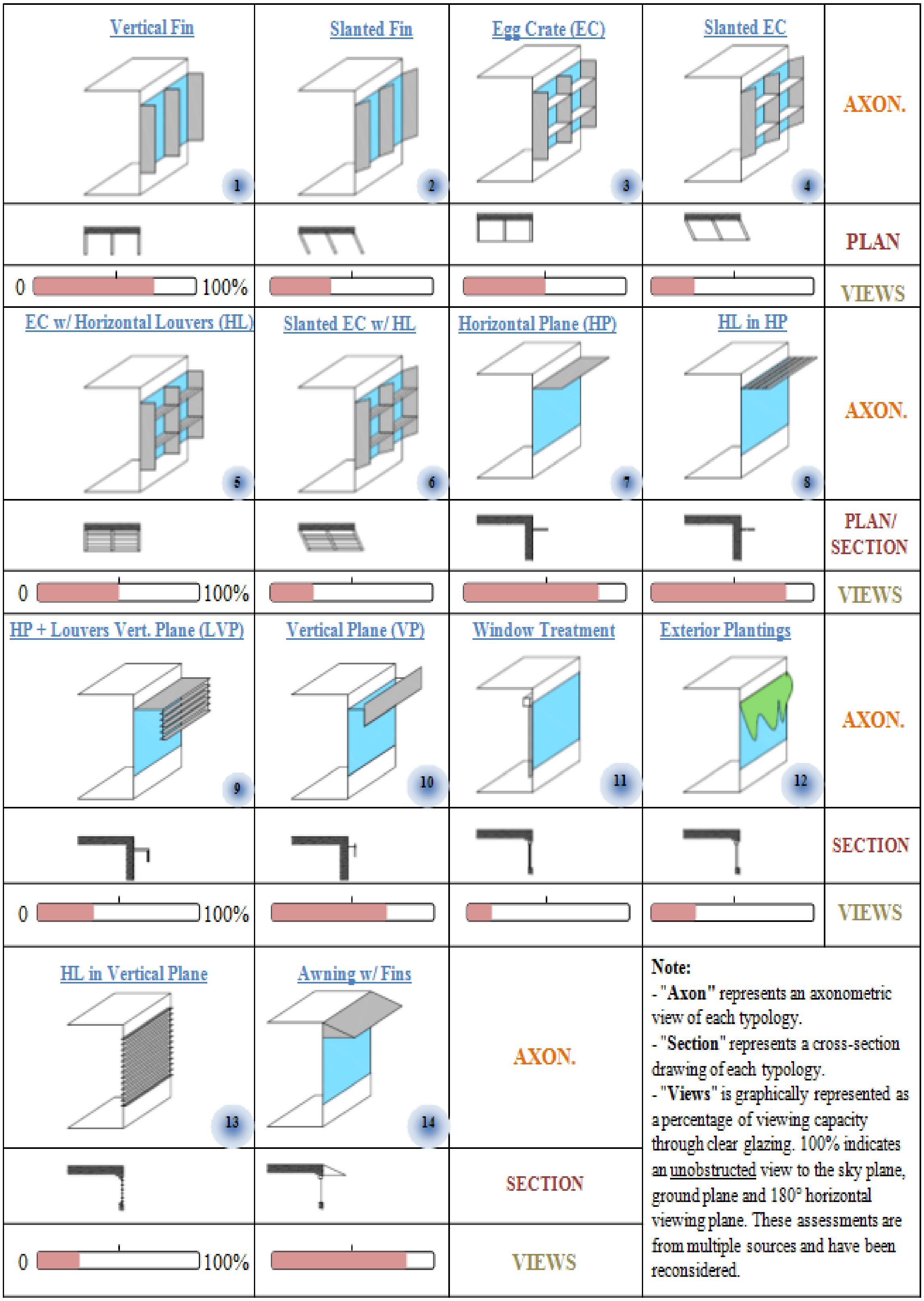

Figure 14: Passive Solar Radiation and Shading Device Typologies for the Modern Office Building Glass Curtain Wall

Multiple Sources: Krishan et al. 2001, Brown et al. 2001, Bassler 2000. Drawings by Author.

following figures will undergo scrutiny in terms of how they attempt to solve the objectives described earlier. This is a complex solution; therefore basic and synergistic passive design strategies will be evaluated. Each will be discussed on their basis of their advantages as well as shortcomings. This effort is being considered to prove the most effective triangulation of combined passive design strategies for shading, solar radiation, and daylighting in addition to maintaining occupant views. It is important to note that this is only part of the consideration though as the subject of natural ventilation and glare will still need to be discussed.

By comparing the suitability of typologies in Figure 14 for an existing low-rise open office building one can attempt to narrow down to the best option. Starting with the exterior planters (#12) resembling terrace gardens and actual plantings this concept should be eliminated. It may require additional costly structural work and perhaps create a dirtier window pane because of unwanted water marks or streaks from rainwater draining through the soil. Planters on a sill may also obstruct views and become difficult to maintain in the sense that it is a growing shading device, which may be difficult to access. Snow loads may also compound the issue. Alternatively, planters mounted to the façade can be considered feasible if they are accessible, do not obstruct views or create a dirtier window or sill and the facade has the ability to handle heavy loads. The only condition which this concept may still deviate from, even with all practical concerns alleviated, is the term *modern*. This solution is clearly not the most simple; using a planting as a shading device. However, it does go to mention that plants can be included for building envelope designs to control solar heat gain while acting as a heat sink.[59] It

[59] Krishan, Baker, Yannas, and Szokolay, *Climate Responsive Architecture*, 76-77.

may also be a more appropriate method for the new building designer to consider as they can correct inadequacies during initial decision making processes.

When referencing Figure 14 (#1), one sees an attempt at offering solutions that do not substantially minimize views. The fixed vertical straight fin has the capacity to defer unwanted solar radiation, primarily for east and west low angle sunlight. It however fails in the effort of offering ample daylighting solutions combined with shading. In effect, lower angle sunlight conditions indirectly diffuse daylight through these windows therefore suggesting less natural lighting from sunrise to sunset. Also, this typology does not shade well against overhead sunlight during mid-day conditions and allows glare to enter the office interior. In comparison to the vertical fin, the slanted vertical fin (#2) has an additional capacity of shading while allowing daylight to enter the space depending upon its rotation. It too fails with the occupant comfort objective of minimizing glare and falls short of shading requirements when the sun is overhead. If it were solely used for shading in a fixed position, the slanted vertical fin may also obstruct more views than the vertical fin.

The egg-crate typology (#3) seems to have evolved from the vertical fin and the horizontal plane of a solid surface. As determined by this review, the egg-crate passive design strategy offers a preferred function. It maintains views, but has limited possibilities when used as a fixed typology. For one, it may minimize the absorption of solar radiation during colder periods of the year due to the additional panels projected in the horizontal dimension. This is not an ideal scenario being there are more heating than cooling degree days for the New York Metro area. However, it should be pointed out that if the egg-crate design strategy were to be correctly situated along a glass curtain wall façade in a tropical climate, the necessity of shading and daylighting may be achieved.

Similarly, the egg-crate with louvers (#5) may be more suitable for a consistently warmer climate and offers further possibility for natural daylighting, depending upon the angles of louvers. However, it still struggles to offer maximum daylighting as a fixed device. Windows are adjacently setback within this typology thereby compounding the shaded cupboard effect. This concept is similar to a bee hive's honeycomb array, but in this case it is squarely shaped. Consequently, these evolved horizontal and vertical plane solutions only pay respect to the exterior and how a shading or daylighting device could be used. This can literally be considered an "out-of-the-box" solution which strives to simplify design complexities to conserve energy. While this is a step in the right direction, it goes to mention that these strategies can be improved, especially with consideration of the interior.

A more basic passive design typology for shading can also be seen in Figure 14 (#7). As identified, the horizontal plane offers the capacity of shading for east, west and south exposures as qualified in the design phase of this project, but is limited by its function when low sun angles are considered. Views are not at all sacrificed with this option, but such solutions do not protect against low angles as well as side angles of solar incidence during warmer periods. These solutions, along with the horizontal louvers in horizontal plane are more commonly seen in the New York Metro area.[60] Figure 15 represents one of the many ways this could work for an actual office building exterior. While louvers offer additional possibilities for daylighting and are capable of sustaining

[60] Author's judgment based on living within this region.

inclement weather conditions, they must be suitably designed as part of an overall scheme to become more effective. Louvers are lighter and have voids for rainwater penetration in comparison to the shading panel projected in horizontal dimension. Louvers additionally allow snow to pass and have the capacity to shade and offer daylighting simultaneously. They are also considered a more "economical solution that can be added to an existing office building envelope as a retrofit" (Hunter Douglas 2012).[61]

Figure 15: Fixed Exterior Louvered Shading Device
Source: Hunter Douglas

The horizontal panel plus louvers in the vertical plane Figure 14 (#9) reduce views due to the additional obstructions of sight. This obstruction will also minimize the effort of absorbing solar radiation during colder periods and create a horizontally sliced view looking outward. The vertical panel alone is possibly the worst solution for a shading device that should also offer daylighting. It will also perform worse than the horizontal plan in providing shading while maximizing views. This type of obstruction is similar to the horizontal louvers in a vertical plane as it will also minimize solar radiation during colder periods. This idea directly combats an important objective of passive design in the New York Metro area.

Providing a fixed shading device to protect against solar radiation while maintaining a maximum line of sight, the most effective typology would be the louvers

[61] "Solar Control," Hunter Douglas, Inc., last modified 2012. Accessed March 3rd, 2012. http://www.hunterdouglascontract.com/solarcontrol/index.jsp.

projected in the horizontal plane. "Deducting the concept of *fixed* and sorting through each of the benefits, the function of each typology can be improved" (Bassler et al. 2000).[62] On these same terms of operability and rotation, one can combine typologies to become even more effective at shading. Specifically, an entirely louvered egg crate shape which that rotates would perform much better than the fixed louvers projected in the horizontal plane.[63] Even this compounded typology can be improved, but it will be with respect to daylighting concerns that one can evolve this subject even further.

Combined Typologies:

Typologies for combined daylighting and shading devices are shown in Figure 16. Similar to the typologies prepared for shading, this information has been collected from multiple sources and then reassembled for further investigation.[64] It has been prepared in section format where vertically filled shapes indicate façade partitions and horizontally filled shapes represent the floor and roof slab. Light grey single lines indicate glazing and black lines indicate shading device outlines which are based on each drawing description. These combined typologies do not encounter every part of the equation in passive design. Natural ventilation strategies have intentionally been omitted for purposes of clarity. Natural ventilation, including window types and the effects of air flow will be discussed later.

Starting from the upper left of Figure 16, typology A (clerestories), offer the capacity for daylighting without glare. By itself, it falls short with respect of having a

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[62] Bruce Bassler, and John Hoke Jr., *Architectural Graphics Standard: An Abridgement of the Ninth Edition; Student Edition*, (New York: Wiley, 2000), 445.
[63] Author's judgment.
[64] Bassler et al. 2000, Brown et al. 2001, Krishan et al. 2001.

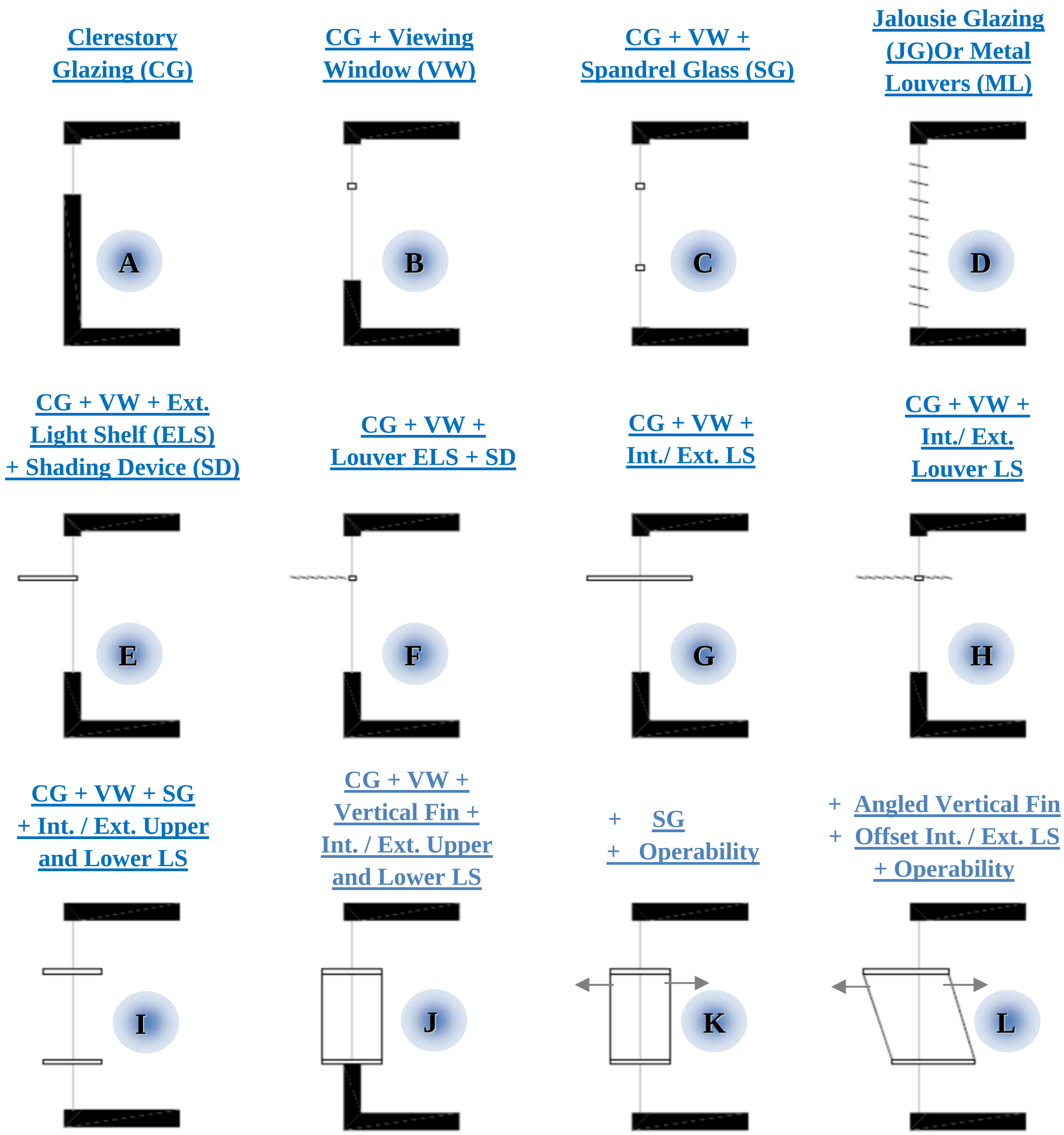

Figure 16: Combined Passive Solar, Shading and Daylighting Typologies for the Modern Office Building Glass Curtain Wall
Multiple Sources: Krishan, DeKay, Bassler. Drawings and Evaluation by Author.

small horizontal surface area to reflect light and typically minimizes occupant views other than the sky plane. When one adds a viewing window (typology B), they have partly responded to this interest by adding occupant views at both the seating and standing level. The unfortunate circumstance from this simple response is the introduction of glare and solar radiation assuming efforts for shading haven't been made. Compounding this effect, the next typology (C) offers even more views from indoor to outdoor and has similar shortcomings, except in this case they are amplified. The horizontal louvers in a vertical plane (typology D) are similar to horizontal window blinds except the surface area is extended and there is additional space between surfaces. If these louvers were able to rotate, they may offer the ability to shade as well as daylight the office interior simultaneously. While this seems very beneficial, they substantially obstruct views into horizontal slices when looking outward. Unfortunately they also pose an issue for using window screens if they are incorporated into the window sash. This information will be expanded upon later when determining the best type of glazing to use. In the next typology (E) one sees the first respect of a light shelf which can also double as a shading device if it were located at the lower mullion of a clerestory window. One also notices the common condition of a framed sill and in some cases spandrel glass in front of this. This combination typology makes an effort to maintain views while shading and naturally daylighting the perimeter part of an office interior. Figure 17 shows what this shelf may look like on the exterior of an office building. The issue that remains with this is that it does not maximize lower angled morning and afternoon daylighting or

Figure 17: Interior Daylighting Shelf
Source: ArchiExpo

Figure 18: Shading and Daylighting Shelf
Source: ArchiExpo

shading throughout the year. Whether these typologies (E through I) are louvered, on the exterior or interior or even solid panels they all share the same objective. The larger the projection in the horizontal direction; the more daylighting and shading opportunity. Thankfully economics, aesthetics and structural load capacities minimize the chance of this becoming increasingly large and obnoxious to the human eye. Since passive design efficiency is what the designer ought to aim for, there is a clear goal in mind and the function is therefore the aesthetic.

By introducing light shelves on the exterior and extending them through the interior (Figure 18) three main goals are achieved. First, is additional daylighting based on the extended horizontal plane. Second, is the additional shading of a view or spandrel window (view window shown in image). Third, is maintaining the line of sight outdoors and therefore the promotion of views. This can occur at both the seated position and when standing if appropriately designed. In comparison to other combined daylighting/shading techniques, typology G and H are an improved concept. Apparently, vertical fins, and a lower light shelf are still missing though.

The next combined typology (I) still falls short in achieving shading, daylighting and solar radiation needs during the occurrence of low sun angles during certain times of the day and year. This shortcoming is substantiated when one looks at the solar azimuth beginning and ending a work day. In terms of timing, this is with respect to the early morning and late afternoon. For instance, this typology would not be able to effectively shade a low sun angle at 9:00am on July 1st when we would prefer to reduce solar radiation, even during the early morning. Additionally, at 9:00am on January 1st, there is additional opportunity for daylighting and solar radiation to warm the interior during the winter.

The simple incorporation of a vertical fin can be added as shown in typologies J and K. This inclusion could be a vertical panel on the exterior which extends through the interior, similar to a horizontal light shelf. In this instance, lower angle sunlight and therefore radiation could either be better reflected or deflected for shading purposes with this additional surface. Typology K shows a similar setup to typology J, but promises equal effectiveness at shading the additional spandrel glazing located below. This proves that this typology could effectively be used where full height glazing is preferred. When compared to the idealized operable and louvered egg crate this solution still falls short of offering the same efficiency. With the incorporation of these additional passive design strategies one might be able to increase daylighting during the morning and afternoon when necessary while simultaneously offering the option to reduce solar radiation during the summer and maximize it during the winter.

When researching climate data even further, one finds that there is additional capacity to reduce the form to the purely functional shape of a rhombus (typology L). In this evolved state the vertical fins are reduced to a surface that can effectively shade on the exterior while offering the option to increase heat gain and daylighting in the interior due to the increased "usable" vertical surface area. Since this bent square accounts for most sun angles and solar azimuths from sunrise to sunset throughout the year in addition to maintaining views this is the best solution (so long as we consider it operable). If it were a fixed device, it would be less than ideal. Coincidently, if this typology excluded louvers for the horizontal as well as vertical planes this would also be less than ideal. Lastly, if this typology did not offer the flexibility of rotation about all of its axes, then there would be a deficiency. Assuming all of these conditions are met, then this typology can be summarized as a set of rotatable vertical and horizontal louvers that are constrained within the form of a 3-dimensional rhombus that maintain views.

Discussion still remains with respect to the design features of the louvers and operability of each plane. The rotatable components and moving parts can be described after mentioning natural ventilation. Specifically, the criteria will be explained in a conjunctive way whereby passive solar, shading, daylighting and natural ventilation design strategies can work together. This of course is to achieve the overall goal of finding the *best* typology. Best can be described as a combined strategy offering the utmost passive design efficiency feasibly available for the modern low-rise open office building in the New York Metro area.

The design features of a louver, its shape, rotation and finish directly correlate to the amount, direction and type of light reflected. According to G.Z. Brown et al. (2001), "the upper surface of a light shelf should be white, or if heat gain is not an issue, then mirrored… a mirrored light shelf with a white ceiling performs better than a mirrored ceiling with a white light shelf. This can be used on all orientations if skies are mostly overcast and for reflecting sunlight on the South."[65]

In Figure 19 we see an interior light shelf as patented[66] that has a capacity to reflect daylighting in a multitude of directions towards the office interior (see Figure 20). The concaved solution here offers better surface reflectivity when compared with a flat or symmetrically concaved louver system. Although not categorized as a typology, the concaved light

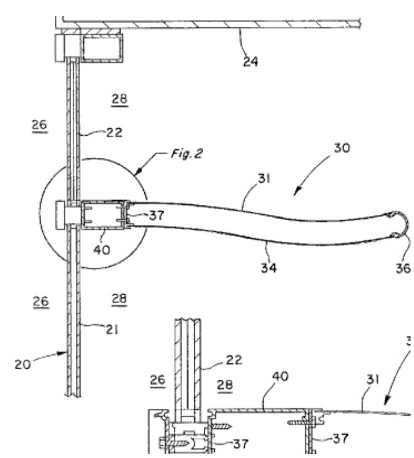

Figure 19: Concaved Interior Light Shelf
Source: Google Patents; US8027092.

[65] G.Z. Brown, and Mark DeKay, *Sun, Wind & Light Architectural Design Strategies: Second Edition*, (New York: Wiley, 2001), 257.
[66] Source: Google Patents; "Concaved Light Shelf"

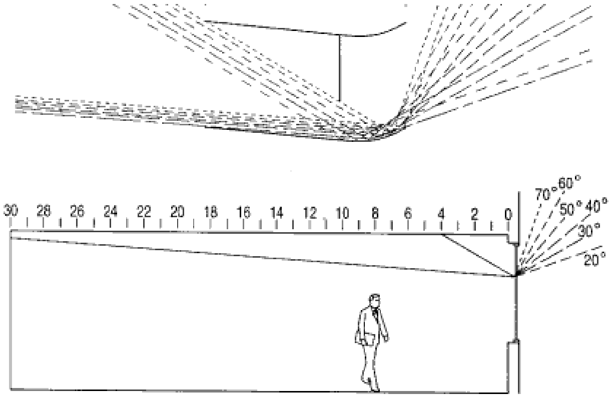

Figure 20: Concaved Light Shelf Reflection
Source: Google Patents; US8027092.

Figure 21: Concaved Light Shelf Example
Source: http://www.lightfair.com

shelf shown in Figures 19 through 21 can "significantly increase daylighting levels in the rear of the space. This possibly reduces the effectiveness at shading lower glazings therefore this device should be lengthened or thickened" (Brown et al. 2001).[67]

It is also noted that "unless a building employs movable devices which can vary the daylight factor in response to varying sky luminance, then the internal daylight illuminance will also vary widely" (Krishan et al. 2001).[68] This understanding suggests even with the specific design of small components, there is still the possibility to affect interior luminance variations. This also means that uncontrollable amounts of shading may occur unless movable shading devices are used. It is clear that the feature of operability is just as important as the overall passive design typology. After determining what and where the light shelf should be used one can use the clear, overcast and optimum light shelf distribution charts in Figure 22 to compare the effects of providing daylighting to certain depths within an office interior.

[67] Brown and Dekay, *Sun, Wind & Light*, 257.
[68] Krishan, Baker, Yannas, and Szokolay, *Climate Responsive Architecture*, 131-132.

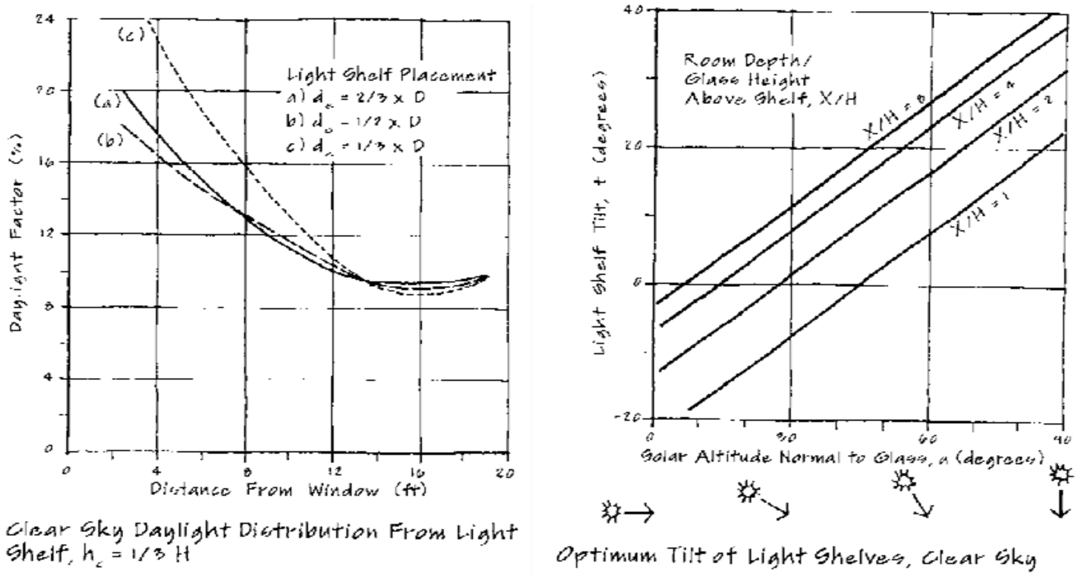

Figure 22: Clear and Optimum Light Shelf Distribution Graphs
Source: Brown et al. 2001.

In the case of daylighting being admitted without causing glare, there are two critical points of elevation that must be considered. As indicated by Figure 23, point A (standing) is about 1.7m above the floor and point B (sitting) is about 1.2m above the floor. Light transmitting between these two points shall be considered glare and shall be avoided at all costs with the objectivity of increasing daylighting at the ceiling; therefore indirectly lighting a space. Criteria regarding externally reflected components (other than

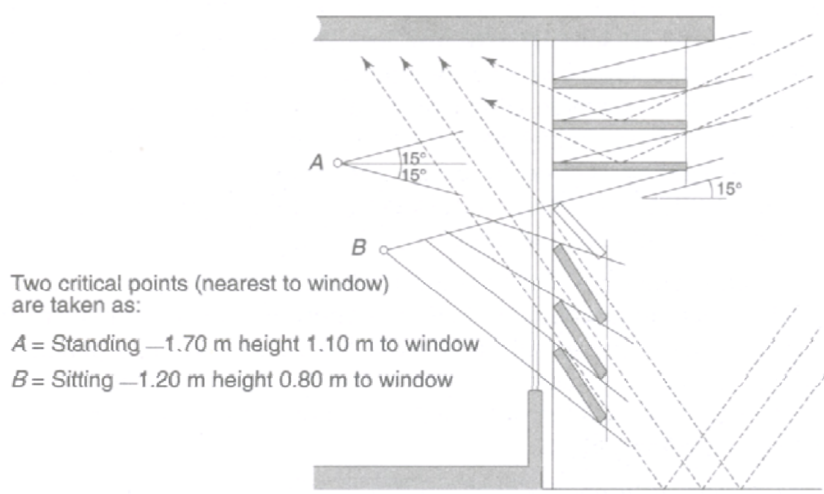

Figure 23: Critical Points for Glare Minimization
Source: Krishan et al. 2001.

the ground) is not included in this research. Such studies will intentionally be omitted as they will substantially vary based on nearby structures, colors of work surfaces, fabrics, floor coverings and the like. The concept of solar radiation is an extension of this subject. The rate at which solar radiation strikes glazing is a function of reflection, absorption and correlates to the angle of incident sunlight.[69]

The simplicity of the venetian blind as well as other window treatments, including the opaqueness of glass, serve the purpose of shading and in some cases insulation, but detract from occupant views. Since this research is based upon maintaining views, daylighting and shading criteria simultaneously, window treatments can be considered limiting and therefore unsuccessful based on the objectives of this research. Other strategies that work for passive solar heating and cooling are the Trombe Michel Wall, thermal mass, window shades, shutters , and window films including low-e coatings.[70] All of which can help to manipulate thermal comfort and daylighting, but if used incorrectly may adversely affect one's level of comfort. According to Arvind Krishan et al., "…window locations make a difference to the quality of light obtained indoors whereby high windows can provide direct and diffuse light and introduce glare and low windows allow ground reflected light. The middle window, in comparison, distributes neither sky nor ground reflected light well" (2001).[71] In summary, daylighting, shading and solar radiation typologies regard three main principles including directness of sunlight, light from the diffused sky and reflectance from the ground and other buildings. Figure 24 illustrates these components which enter a room, particularly a work plane. All

[69] Krishan, Baker, Yannas, and Szokolay, *Climate Responsive Architecture*, 140-142.
[70] Krishan, Baker, Yannas, and Szokolay, *Climate Responsive Architecture*, 68-83.
[71] Ibid., 40.

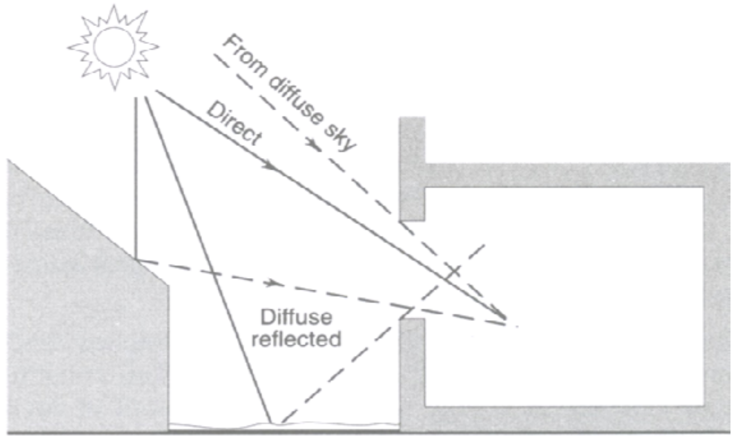

Figure 24: Daylighting Illumination; Directness, Diffused and Reflected
Source: Krishan et al. 2001.

are part of the larger study regarding daylight factors and deal with the illuminance inside the building versus the outside. This suggests that artificial lighting must respond to this variation based on the most efficient passive design strategy that can be used as a retrofit. "Once a late modern building has been improved to include as many daylit areas as possible, we are ready for the next and sometimes forgotten step. Daylighting has no sustainable energy benefit if the interior lights are left on" (Gelfand et al. 2012).[72] This step will not be forgetten and will be addressed by the overall retrofit strategy as contained in the design phase of this project. The main purpose is to maintain a balanced level of these conditions within the office interior while maintaining views.

As described earlier, the 3-dimensional louvered rhombus is the most successful passive design typology for combined daylighting, shading and solar radiation while maximizing views in both a seated and standing position. It is recommended that by including automated devices which respond to variable environmental conditions this retrofit typology may be able to operate on its own. Photometric sensors, anemometers

[72] Gelfand and Duncan, *Sustainable Renovation Strategies*, 130.

and thermostats should be programmed to work in equilibrium with this unit in order for it to be highly efficient at maintaining thermal comfort. While calculations are offered at determining the best solar angle of these louvers at different times of the day, month and year, it shall be assumed that an automated system would be able to control thermal comfort if programmed correctly. For this reason, louver angle calculations will intentionally be omitted from this research project as this feature is not easily determined with computer simulation.

Material Properties of Aluminum

pp 63-66

Material Properties of Aluminum:

Anodized aluminum offers the flexibility of polishing to a reflective finish while suitably holding up to the effects of the New York Metro area freezing, thawing, heat, cold and rain. In addition to its durability, anodized aluminum allows for multiple capacities of drilling, on-site cutting, welding, and is lightweight and recyclable. It is also readily available and economical. G.Z. Brown et al. recommends that the "underside of louver shading devices and light shelves to be light in color and drilled with tiny perforations to reduce glare" (2001).[73] In this condition, aluminum has the ability to maintain its rigidity even with the inclusion of these perforations. This can be seen in the shading device design strategy for the Middle School project located in Cowplain, England (Figure 25).

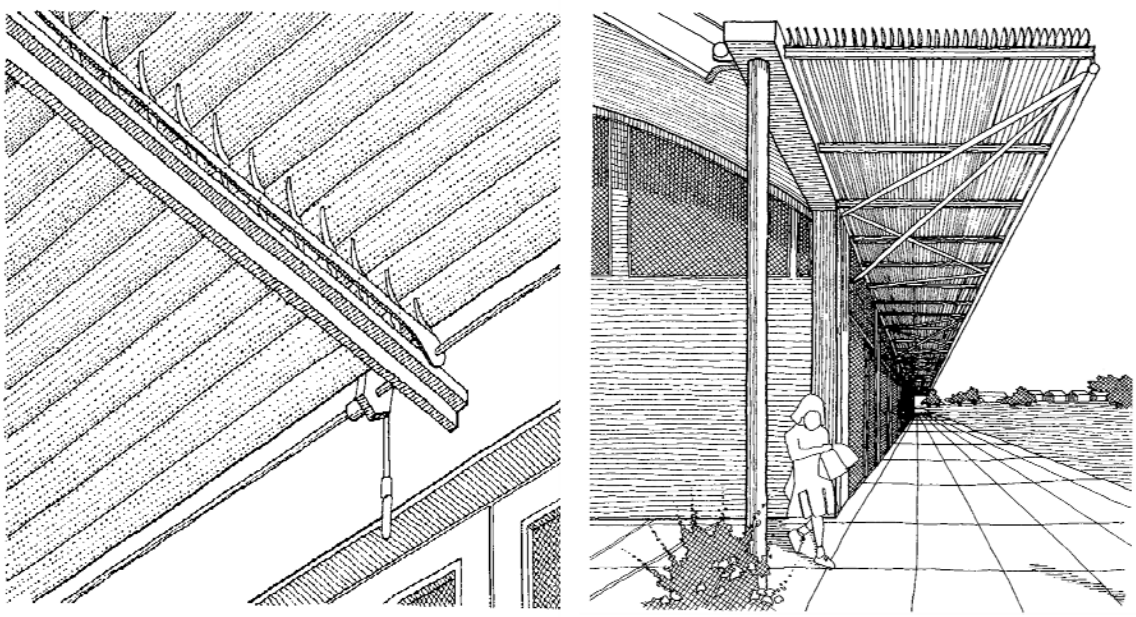

Figure 25: Extruded Aluminum Louvered Shading Device With Perforations (Cowplain, England Middle School Project)
Source: Brown et al. 2001.

[73] Brown and Dekay, *Sun, Wind & Light*, 261.

Aluminum's properties are naturally made up of a component of the Earth. Being the most abundantly available of the metals, "aluminum makes up approximately 7-8.2% of the Earth's crust" (ASM 2012).[74] The element of aluminum is not found by itself as it is typically combined with other natural elements. "The most common elements that aluminum combines with are potassium aluminum sulfate and aluminum oxide" (IAI 2012).[75] ALCOA Inc. (2012), a world producer of aluminum, categorizes this metal as material number 6601; "having excellent joining characteristics, and a good acceptance of applied coatings."[76] Aerospace Specification Metals, Inc. also states that aluminum has a relatively high value of strength, good workability, high resistance to corrosion and can be made in many shapes and sizes (2012).[77] See Figure 26 for examples of extruded aluminum mullion formations and a microscope sampling.

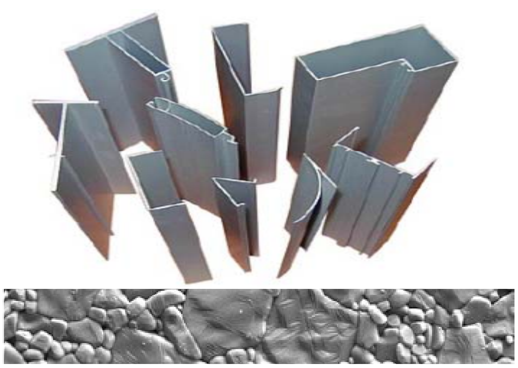

Figure 26: Extruded Aluminum Mullion Formations and Fired Aluminum Oxide (Al_2O_3) Microscope Sampling
Source: http://www.spie.org

The density of aluminum is found to be ".0975 pounds/cubic inch and its modulus of elasticity is 10,000 kips/square inch" (Ophardt 2003).[78] Aluminum has the symbol "Al" and is derived from the Latin word *alumen* meaning alum.[79] Its atomic number is

[74] "Aluminum," Matweb LLC and Aerospace Specifications Metals, Inc., accessed April 7th, 2012, http://asm.matweb.com/search/SpecificMaterial.asp?bassnum=MA6061t6.
[75] "Story of Aluminum," International Aluminum Institute, last modified 2012. http://www.world-aluminium.org/About+Aluminium/Story+of.
[76] "Finishes; Anodized Finish Specifications," ALCOA, Inc., last modified 2012. http://www.alcoa.com/kawneer/north_america/catalog/pdf/Finishes--A.pdf.
[77] International Aluminum Institute. "Story of Aluminum," last modified 2012.
[78] "Virtual Chembook; Aluminum AL," Ophardt, Charles, Elmhurst College, last modified 2003. http://www.elmhurst.edu/~chm/vchembook/102aluminum.html.
[79] Ibid.

13 and atomic mass is 26.98.[80] Aluminum is shiny, silvery white in color and is relatively lightweight yet heavy enough to sink within water (Ophardt 2003).[81] According to research, aluminum is covered with a layer of oxide which blocks the exposure to air and harmful elements (IAI 2012). If this layer is damaged for any reason then it would become more vulnerable to the surrounding environment. The molten hot chemical composition of aluminum oxide is Al2O3 and is processed electrolytically for means of production.[82]

The potential for aluminum to meet modern sustainability trends is high. Research suggests that most of the available aluminum products are currently made up of 50% post-consumer recycled content.[83] According to International Aluminum Institute (IAI), "aluminum is the second most used metal, behind steel" (2012).[84] IAI also states that aluminum is a unique metal; strong, durable, flexible, impermeable, lightweight and as mentioned earlier, it does not rust.[85] Most importantly it meets the demand for a sustainable future by having the capacity to be 100% recyclable. Although these are very respectable traits for a material to have it should be known that aluminum is not renewable although it is available in large quantities. According to IAI, "there was approximately 34 million tons of aluminum produced in 2006, whereas 16 million tons were recycled" (2012).[86] This statistic reinforces the 50% post-consumer recycled content value referenced earlier. Aluminum should be used in place of other materials that will rust or potentially be less recyclable for exterior shading and daylighting.

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[80] Ibid.
[81] Ophardt. "Virtual Chembook; Aluminum AL," Elmhurst College, last modified 2003.
[82] International Aluminum Institute. "Story of Aluminum," last modified 2012.
[83] Ibid.
[84] Ibid.
[85] Ibid.
[86] Ibid.

Natural Ventilation

pp 67-77

Openings: Location, Type and Size

Since "people spend almost 90% of their time inside of buildings" and open spaces make up more than 80% of the open office building space plan, cross ventilation criteria is an important factor to consider (Syed 2012).[87] This research is particular to that of large shared spaces rather than individualized areas. According to Arvind Krishan et al., "the average internal wind speed can be determined as a percentage of external wind and for the condition of cross ventilation is based on the area of openings" (2001).[88] Wind velocities are expected to decrease across open areas as "natural ventilation that is not assisted by fans requires a high pressure difference" (Gelfand et al. 2012).[89] Also in some cases this decrease in air pressure may be due to obstructions caused by furniture. Since this is a complex variable it will be omitted for the purposes of presenting concise research. Attention will therefore be based on the effects of natural ventilation for an open space, rather than one with furniture (see Figure 27).

"Late modern office buildings can benefit from passive ventilation by offsetting heating and cooling loads, but are heavily contingent upon reducing internal heat gains prior" (Gelfand et al. 2012).[90]

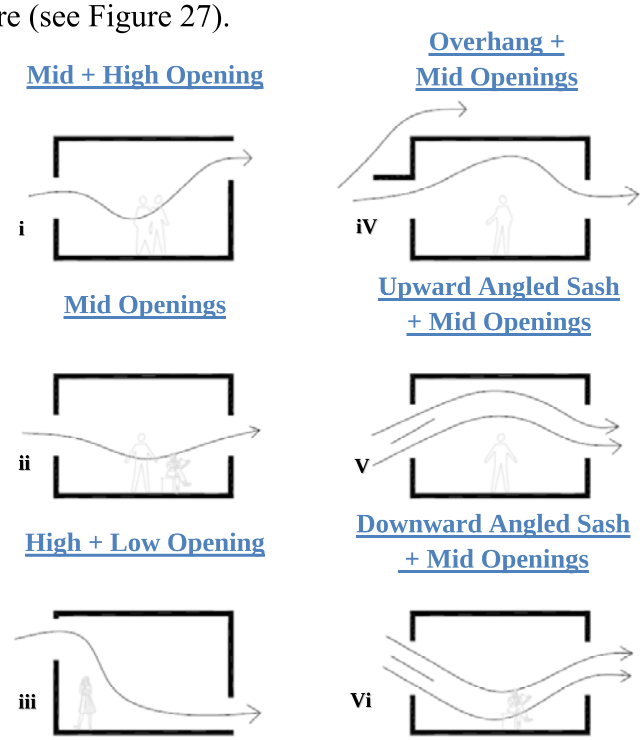

Figure 27: Cross Ventilation Options Based on Opening Location and Type
Multiple Sources: Krishan, Brown and DeKay, Bassler. Drawings by Author.

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[87] Syed, *Advanced Building Technologies*, 7.
[88] Krishan, Baker, Yannas, and Szokolay, *Climate Responsive Architecture*, 156.
[89] Gelfand Duncan, *Sustainable Renovation Strategies*, 35.
[90] Ibid., 128.

By determining cross-ventilation typologies (Figure 27) alongside the study of shading, daylighting and solar radiation one can triangulate the most ideal passive design strategy for a retrofit project. Window operation will be based on natural ventilation strategies with respect to weather and other conditions affecting the building envelope. The purpose of using natural ventilation when outdoor air temperatures are between 62° and 80°F (summer passive zone) is to pass air across and over the human body to produce a cooling affect while introducing fresh air. One must decide the best way to do both of these during this time.

According to indoor air conditioning studies, "only 15-20% of the total air circulating is typically outside air, 80-85% is recirculating air" (Syed 2012).[91] The United States Green Building Council has responded to this issue by encouraging more outdoor air-flow for LEED Certified buildings; offering more points for an increase.[92] Clearly, bringing in fresh outdoor air is an important measure in buildings and it is gaining more consideration. The most objective response to do this passively would be to facilitate the use of window sashes in a way that air moves at a mid-lower level of the office interior. During periods where thermal comfort has been achieved, airflow can be deferred toward the upper volume of the space; above those who may be sitting or standing Figures 27 (V) and 29 (1). Accordingly, cross ventilation offers the ability to "distribute heat more evenly throughout a structure" (Krishan et al. 2001).[93]

As mentioned earlier, the middle hung and awning window works best for purposes of pitching rainwater (including lower angled rainwater) away from the building

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[91] Syed, *Advanced Building Technologies*, 7.
[92] USGBC, *LEED for Commercial Interior Reference Guide Version 2.0: Third Edition*, (District of Columbia: United States Green Building Council, 2008), 283.
[93] Krishan, Baker, Yannas, and Szokolay, *Climate Responsive Architecture*,, 159.

and likewise protects the interior during stronger wind events. Unfortunately, the middle hung window does not offer the flexibility to include a window screen as it rotates at a middle pivot point (hence middle-hung). This poses a potential issue for the low-rise open office building in the New York Metro area. The influence of wind flow in a room based on a buildings orientation and amount of window openings also shares relevance in determining the best use of natural ventilation. In determining the most likely event for the low-rise open office building with a central support core we can appropriate some of the following conditions. Sample wind flow typologies with respect to prevailing winds can be seen in Figure 28 and 29.[94] Figure 30 shows that interior solar heat gain is less

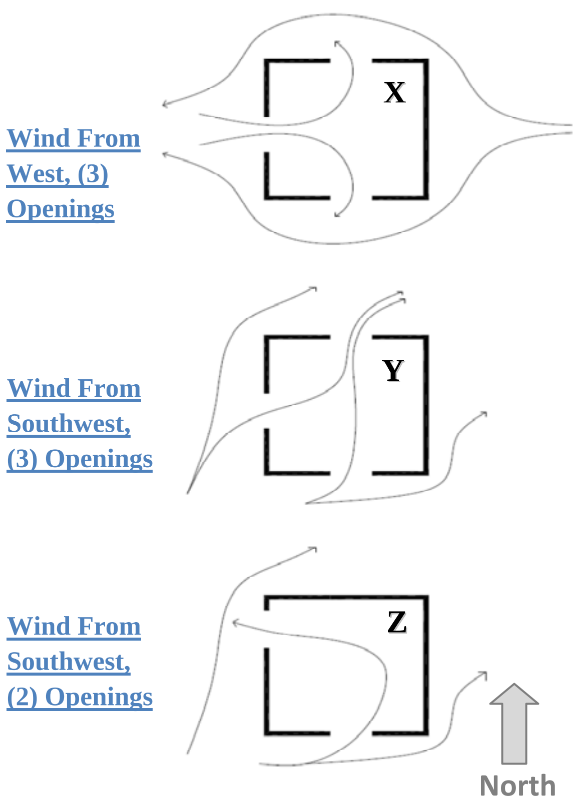


Figure 28: Plan Views of Prevailing Wind and Cross Ventilation Strategies Based on Opening Location
Multiple Sources: Krishan, DeKay, Bassler.

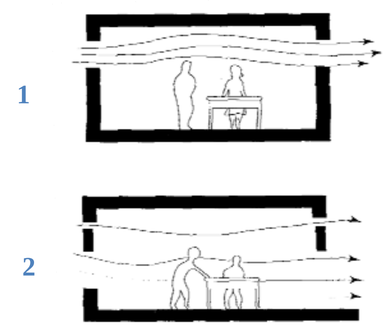
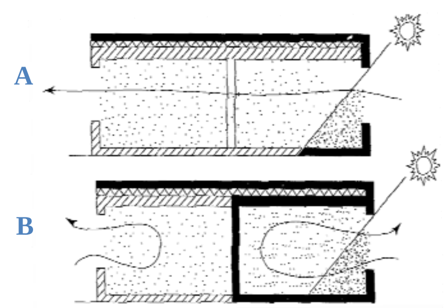


Figure 29: Air Flow Passing Occupants Sitting and Standing
Source: Krishan, 161.



Note: Dark dots represent areas of direct solar heat gain.

Figure 30: Distribution of Solar Heat Gain:Single Sided Ventilation Vs. Cross Ventilation
Source: Krishan, 161.

[94] Brown and Dekay, *Sun, Wind, Light*, 20, 39, 163.

distributed in a compartmentalized space with glazing and single sided natural ventilation (B) versus an open space with glazings and cross ventialation (A). It should also be mentioned that the quantity and location of glazings and wall locations make a difference for daylighting, natural ventilation, heat gain. heat loss, shading and views.[95]

Research shows that the "four primary means of natural ventilation can be achieved using single sided ventilation, cross ventilation, the stack effect and reverse stack effect" (Krishan et al. 2001).[96] Since the building typology being studied is the modern low-rise open office and particularly retrofits to passively improve them, feasibility and economical considerations play an important role. Respectively, the stack and reverse stack effects (Figure 31) will be dismissed as they shall be considered uneconomical solutions for a retrofit project, particularly an open office building which contains a central masonry core and support spaces. However, there is one condition that may be feasible to some extent, but will also be purposely omitted; the buoyancy driven ventilation stack which would perform best during winter months whereby air would be preheated by a perimeter element. This is similar to the concept of a continuously open chimney that may help to increase air movement and changes across an open floor plan in addition to

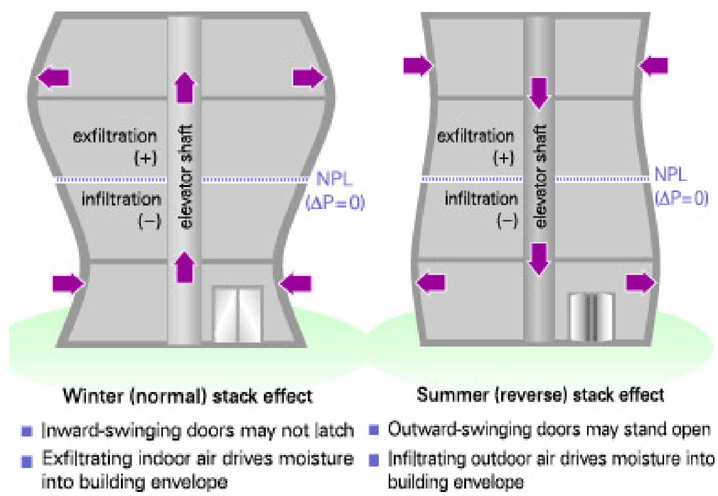


Figure 31: Stack and Reverse Stack Effects
Source: http://www.trane.com/commercial/library/vol31_2/.

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[95] Krishan, Baker, Yannas, and Szokolay, *Climate Responsive Architecture*, 41.

[96] Krishan, Baker, Yannas, and Szokolay, *Climate Responsive Architecture*, 155.

the levels above it. It however uses a mechanical heating device in order to preheat incoming natural ventilation.[97] In effort to maintain a largely passive heating and cooling solution, this typology will not be considered further.

The study of openings for increased ventilation show that window configurations can have significant effects on the flow of air. Accordingly, the orientation, mounting height and window typology makes all the difference. For instance, a sash which angles air in and upward allows air to carry its velocity primarily towards the ceiling whereby a sash angling down and inward does the opposite. This concept was shown in Figure 27 and is also of reference to Figure 32. Likewise, the mounting elevation of the window shares a similar function. Windows located closer to the floor have a different effect when compared with windows located at a higher elevation. According to multiple sources, "The window fenestration height should be such that there is a good distribution of airflow across the human body. Lower sill levels are preferable and in cold climates window fenestrations should be large, unshaded, but sealed to prevent cool drafts" (Krishan et. al 2001).[98]

[97] Ibid., 48.
[98] Krishan, Baker, Yannas, and Szokolay, *Climate Responsive Architecture*, 41.

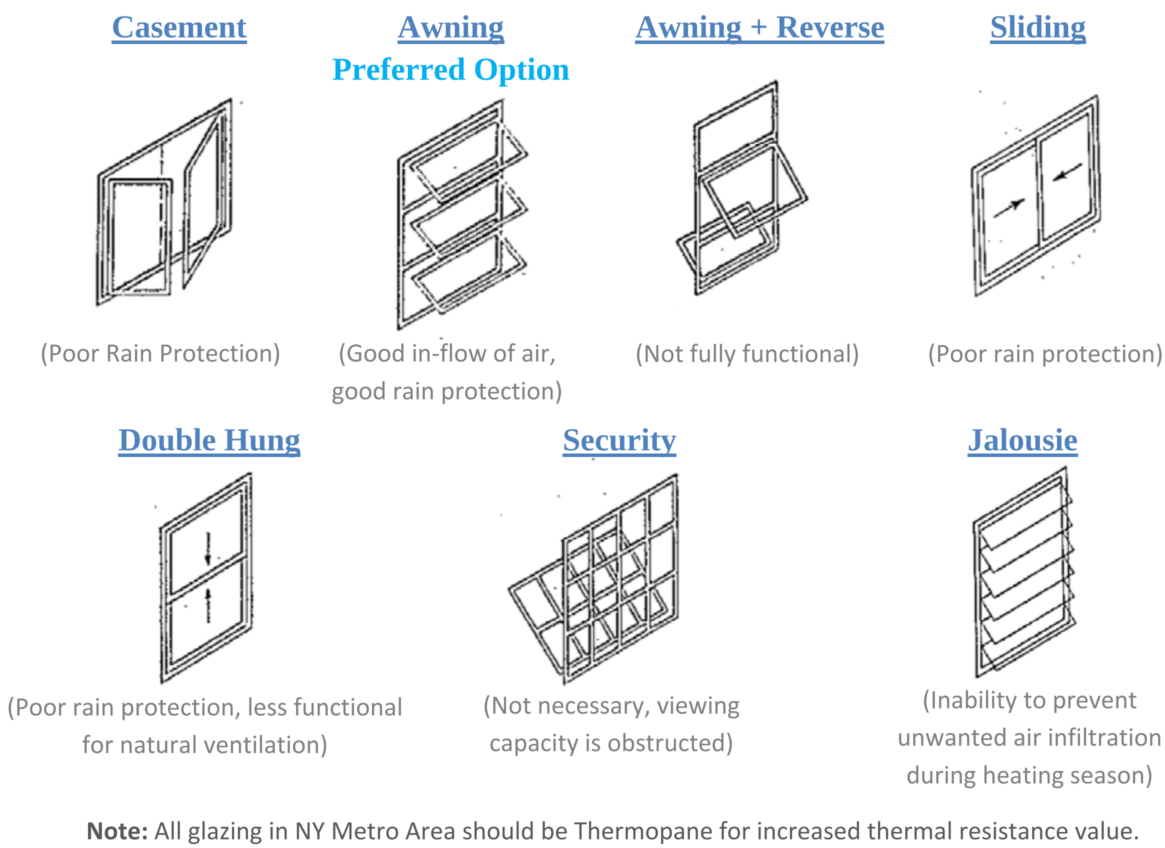

Figure 32: Metal Operable Window Types That Allow Insect Screens
Source: Architectural Graphics Standard, 2000.

The path of air and natural light travel can thus be considered somewhat controllable based on the type of window, its orientation, elevation and dimensional criteria. According to research, “Window cross-sections have the ability to affect fluid flow velocities; increasing the cross-section can decrease the entering wind speed and vice versa” (Krishan et al. 2001).[99] These become important considerations in the case for retrofit selection criteria and will be used as a key design component. As derived from daylighting, shading, natural ventilation, water penetration and other environmental studies the best windows as shown in Figure 32 for a comprehensive plug-in retrofit

[99] Krishan, Baker, Yannas, and Szokolay, *Climate Responsive Architecture*, 43.

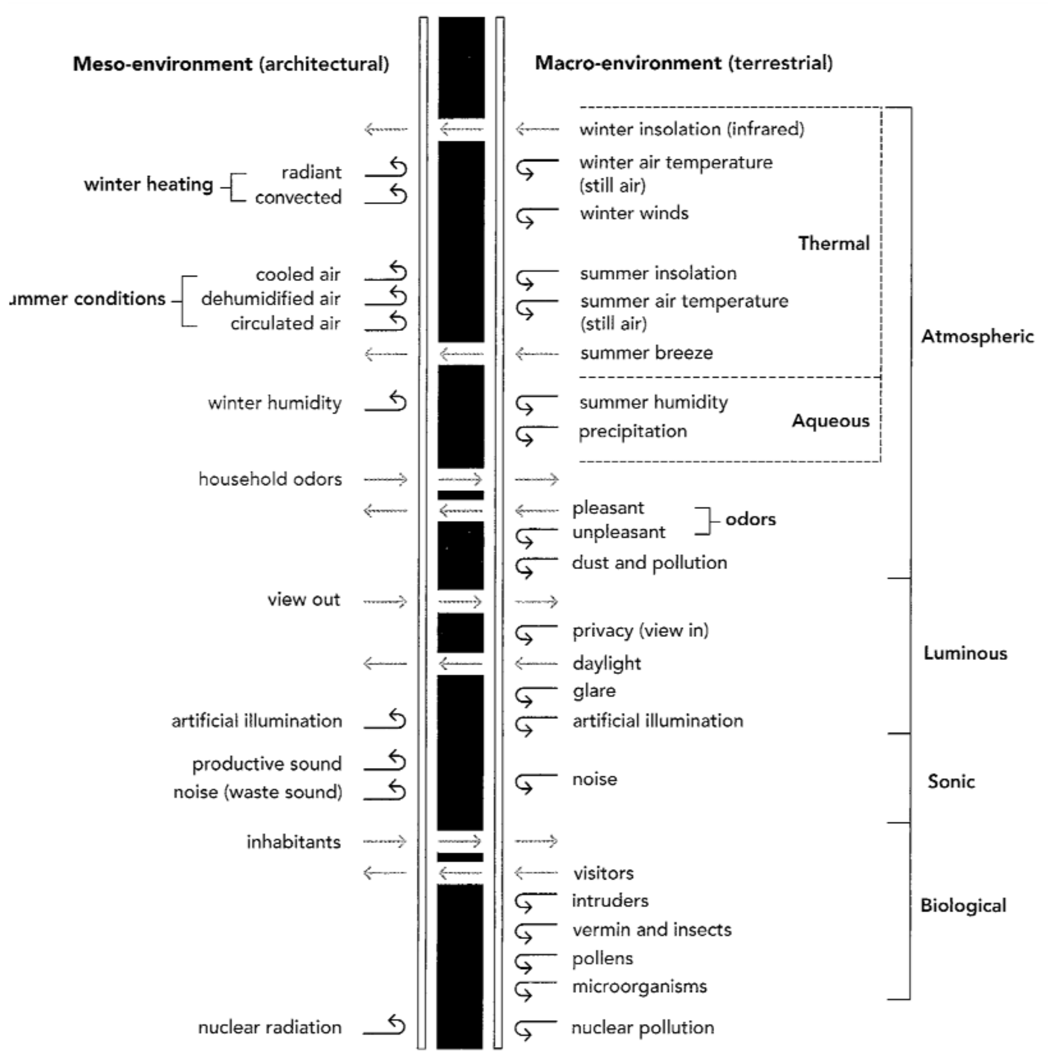

Figure 33: Building Envelope as a Selective Filter of Macro and Micro Environmental Factors
Source: Contemporary Curtain Wall Architecture, 2009.

solution would be the awning window with clear fiberglass bug screens. One can therefore say that the middle hung window is no longer the best option even if it can be controlled by automated devices. This is because the building needs to protect against the "Macro-environmental conditions of dust, vermin, insects and pollens in addition to microorganisms whereby the building envelope must perform as a selective filter of them" (Murray 2009).[100] Figure 33 demonstrates this additional complexity.

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100 Murray, *Contemporary Curtain Wall*, 74-75.

For the New York Metro area office building bug screens come in handy and may not suitably be used with other window types that allow air inflow at controlled angles. Alternatively, this is where certain windows can provide a better function over others. A small list to identify where and how one should use natural ventilation is bulleted below.

•"Window locations should be offset with respect to opposite and adjacent facades, rather than aligned in plan, unless prevailing wind is at an angle.

•Partitions or walls should not be placed by windows.

•Windows on adjacent curtain walls should not be placed in a way to cause an abrupt change in wind direction when opened simultaneously.

•Indoor air speeds are larger with outlet windows bigger than inlet windows.

•A window section has the ability to divert, deflect and increase/ decrease wind speed" (Krishan et al. 2001).[101]

This information is also useful for core support spaces in buildings as well as those with double loaded corridors. The natural ventilation opportunity that presents itself here could be achieved with the use of louvered doors and openings acting as air inlets and outlets rather than entirely closing these central spaces. On the same note, elevator lobbies, corridors and hallways even have the option of using transom windows and overhead vents for cross air flows even if security concerns arise. Figure 34 shows these options with respect to the typological section through an open office building. With this in mind, the core support spaces may also be improved with the opportunity of natural

[101] Krishan, Baker, Yannas, and Szokolay, *Climate Responsive Architecture*, 43.

ventilation and in a few cases, ambient daylighting. Air volumes of, by itself, has the capacity to make indoor conditions more comfortable, so long as they move. Also,

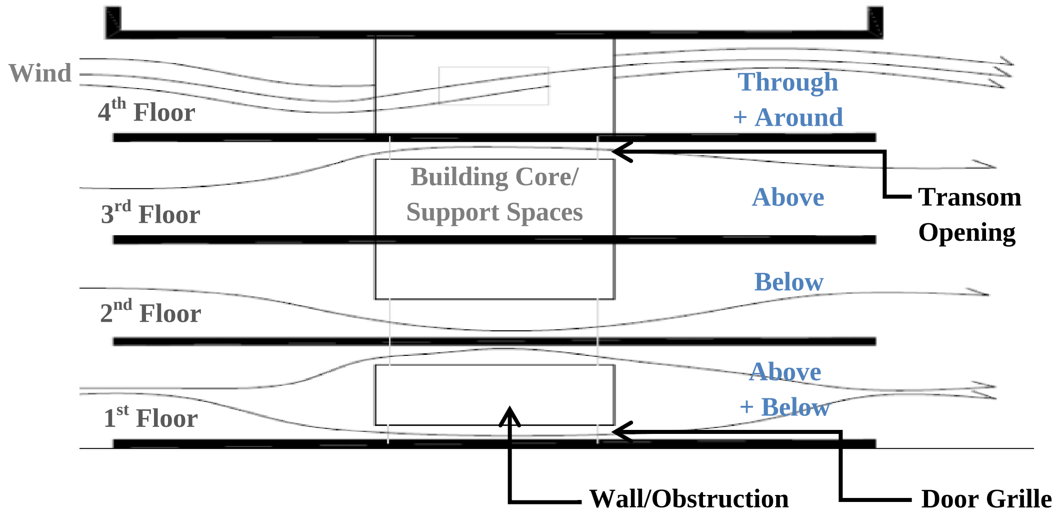

Figure 34: Example of Cross Ventilation
Options Through Open Office Building Section (Including Core)
Multiple Sources: Krishan, 149. DeKay, Bassler. Drawing by Author.

interior fire separation criteria will also need to be evaluated at the time of locating interior and exterior window openings. Such criteria involves maintaining fire rating longevities between interior partitions, doors, windows and duct/pipe penetrations as required by the size of open office areas. Since this research project pertains to a building envelope retrofit, major interior improvements will not be considered. This information is therefore made available to promote the passive design idea of being thorough. Figure 35 shows the preferred natural ventilation typology as previously discussed. Darkened lines represent double awning windows placed in an existing building curtain wall system, as part of the idealized retrofit strategy.

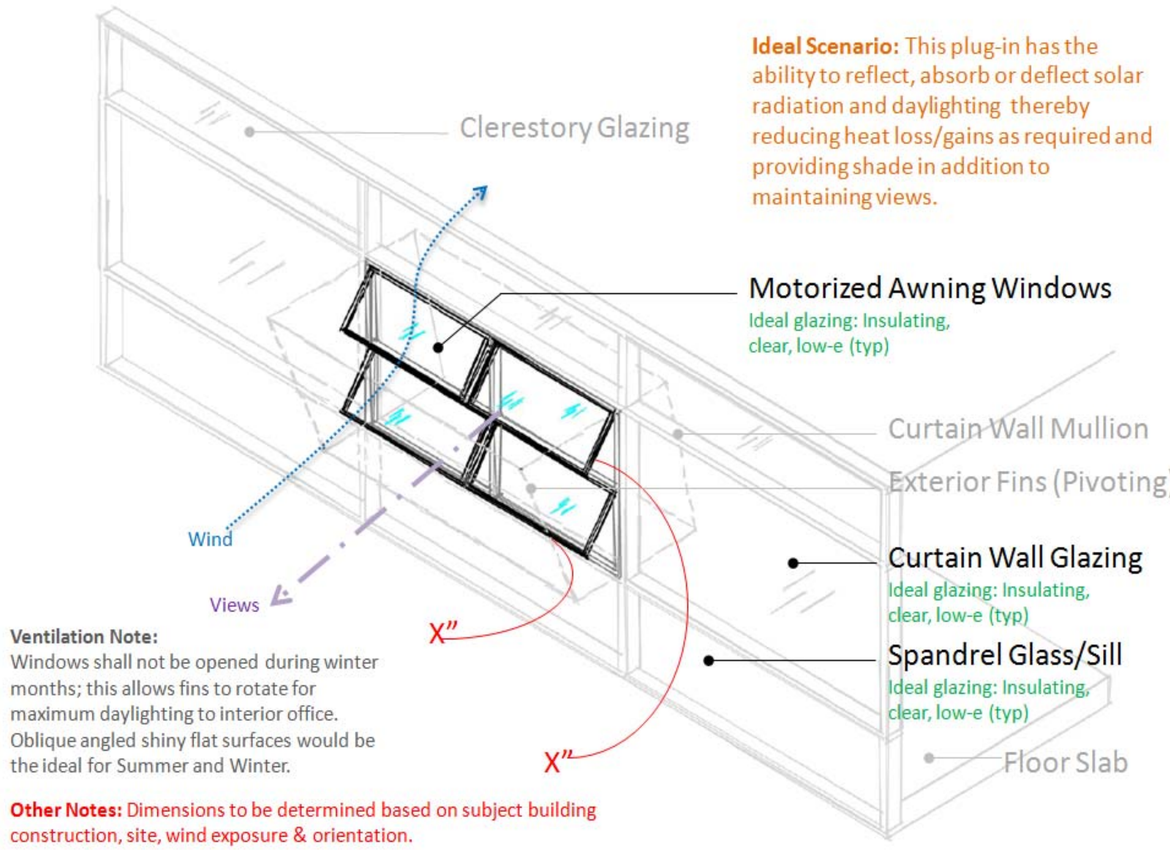

Figure 35: Axonometric of Awning Windows Contained in Idealized Retrofit Typology
Source: Drawing by Author

Glazing and Views

pp 78-84

Properties:

Glazing selection becomes another important subject to consider for the building façade retrofit project. It has the ability to allow natural ventilation, reflect, absorb or deflect solar radiation and daylighting in addition to reducing interior heat loss and gains when needed. As contained in the idealized retrofit Figure 36, glazing is hatched in blue.

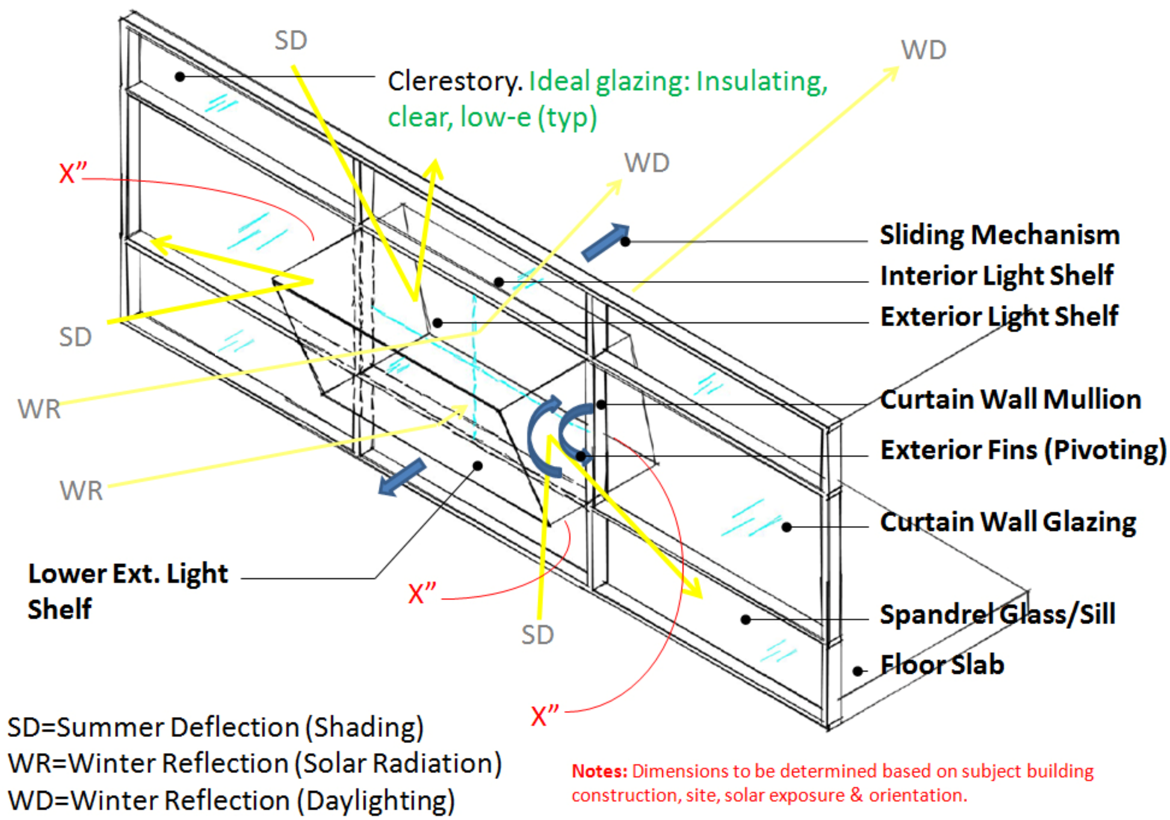

Figure 36: Axonometric of Idealized Retrofit Contained in Glass Curtain Wall System
Source: Drawing by Author

When establishing criteria for selecting the best type of glazing and framework for a facade retrofit one should compare the cost difference between modifying the existing glass and curtain wall framework and replacing it with new. This consideration should be made in addition to analyzing the function of how each performs. As identified from Table 6, a single pane clear glass window offers a higher solar gain factor (SGF) when shaded than a reflective double pane 6mm glass window pane that is sealed and in direct sunlight.[102]

Table 6: Solar Gain Factors for Windows
Source: Krishan et al. 2001.

	Instantaneous sgf	*Alternating (asg) lightweight*	*heavy bldg.*
Single glazing			
clear 6 mm glass	0.76	0.64	0.47
surface tinted	0.60	0.53	0.41
body tinted	0.52	0.47	0.38
clear, reflective film	0.32	0.29	0.23
strongly reflective glass	0.18	0.17	0.15
Double glazing			
clear + clear, 6 mm	0.64	0.56	0.42
surf.tinted + clear, 6 mm	0.48	0.43	0.34
body tinted + clear, 6 mm	0.40	0.37	0.30
reflecting + clear, 6 mm	0.28	0.25	0.21
strongly refl. sealed unit	0.15	0.14	0.11
With external shading			
single, clear, light horiz. salts	0.16	0.11	0.09
single, clear, light vertic. salts	0.18	0.13	0.10
single, clear, holland blind	0.13	0.10	0.08
double, clear, light horiz. salts	0.13	0.09	0.07
double, clear, roller blind	0.10	0.09	0.07

Table 7: Comparative U-values and Light Transmittance Through Different Glazing Types
Source: Murray 2009.

COMPARISON OF INSULATING GLASS PERFORMANCE
All examples assume 1/4"thick inner and outer glass panes with 1/2" air space

INSULATING GLASS TYPE	VISIBLE LIGHT TRANSMITTANCE	VISIBLE LIGHT REFLECTANCE	SHGC	WINTER U-VALUE
Clear glass, uncoated	79%	14%	0.70	0.47
Gray glass, uncoated	41%	7%	0.48	0.47
Clear glass with reflective coating	12%	33%	0.18	0.40
Clear glass with low-e coating	70%	11%	0.38	0.29
Gray glass with low-e coating	35%	6%	0.24	0.29
Clear glass with low-e coating and ceramic frit pattern (50%)	44%	22%	0.26	0.29
Clear glass, uncoated, + argon fill				0.45
Clear glass, low-e + argon fill				0.25
Triple glazing, clear glass, uncoated				0.31
Triple glazing, clear glass low-e + argon fill				0.14

[102] Krishan, Baker, Yannas, and Szokolay, *Climate Responsive Architecture*, 106.

The idea that this window will be shaded during the day and the building will unoccupied during the night helps decision making. It's clear that this is not only a matter of reducing heat gain during the summer or maintaining indoor temperatures after operating hours. More importantly, it is about the mediation between indoor and outdoor environmental conditions combined with the optional phenomenological *greenhouse* effect during cooler periods. In addition to the interest of increasing solar gains during the winter, the opacity of clear glass also offers better viewing clarity, a higher solar heat gain coefficient (SHGC), and more visible light transmittance (VLT) according to Table 7.

Performance Values:

Typical insulating glass performance values are supplied in Table 7 and are useful for comparison. According to this figure uncoated single pane clear glass has a visible light transmittance of 79%, but has a poor U-value of 0.47 (Murray 2009).[103] The U-value "measures heat transmission (thermal resistance) from one side of the glass to the other and is the inverse of a resistance value (R-value=1/R), normally used for determining insulation" (Syed 2012).[104] In the case of U-values, a smaller number means better insulation and thermal resistance capacity.

Also by adding a low-emissivity (low-e) coating to this glass, visible light transmittance is minimally decreased (by -9.0%) while visible light reflectance is reduced (by -3.0%) and the U-value is decreased by more than 35%. When comparing the improved option with triple glazing plus low-e argon fill the U-value is decreased by

[103] Murray, *Contemporary Curtain Wall*, 76.
[104] Syed, *Advanced Building Technologies*,124-125.

more than 50% and allows similar visible light transmittance. This is the preferred option for orientations which receive more shade and less direct sunlight. However, multi-pane glazing requires special considerations "...they are unique to increasing cost, thermal performance and acoustics. In the case of incorporating large windows or clear glass, multi pane windows generally pay back the higher cost in very cold climates" (Syed 2012).[105] Figure 37 provides a better understanding of these resistance values, and heat flow principles, including air infiltration, through a sampling based on time. It can therefore be used as background information for the important subjects of heat loss and gain. Fortunately, Ecotect 2011 has the ability to calculate these forms of heat flow. This affords speedier calculations for environmental analysis when adjusting building envelope materials, finishes and times of the year.

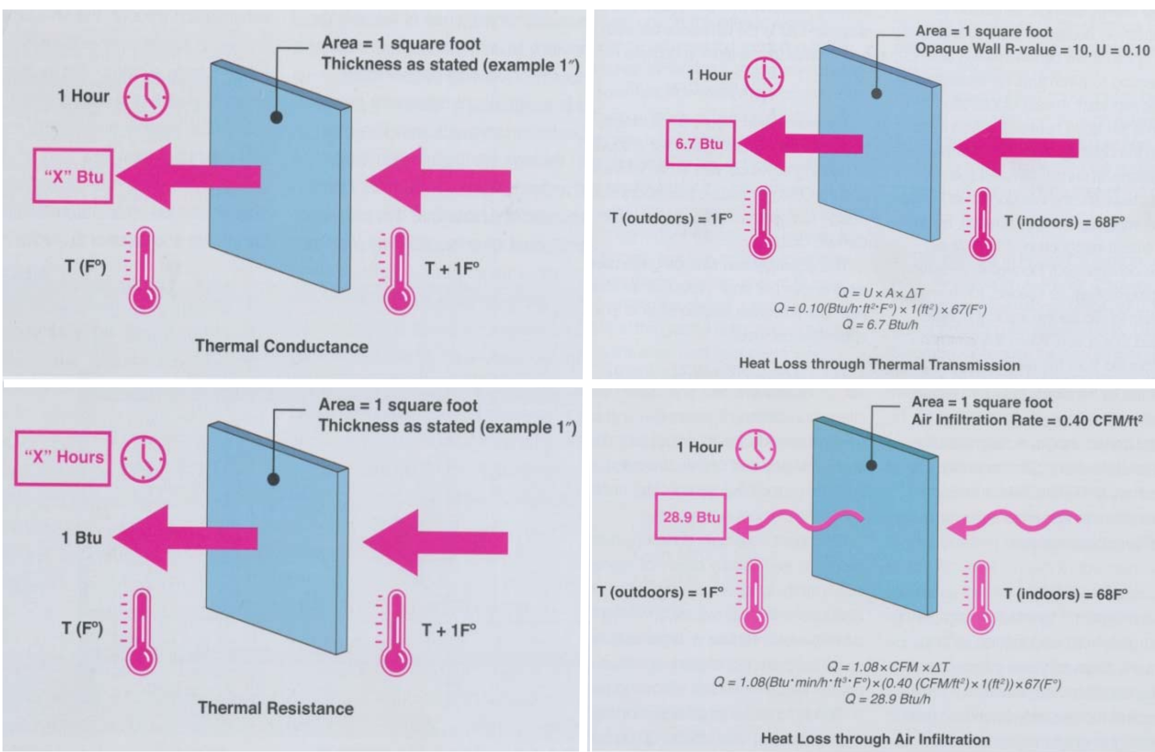

Figure 37: Thermal Conductance,
Resistance, Transmission and Air Infiltration Diagrams
Source: Hootman, 2012.

[105] Syed, *Advanced Building Technologies*, 139.

Clear glass also creates less condensation when compared with reflective or tinted glass as warmer glass means less condensation (Elsier 2007).[106] For these reasons clear glass windows could be considered uniquely efficient, although contrary to popular belief. While this research is not aimed to suggest the single pane clear glass viewing window over insulated glazing, it does show that the macro condition of using passive design strategies may outweigh common assumptions. The concept of using tinted or reflective film windows on glazing solely to prevent unwanted heat gains and losses goes against our main goal. This goal should be based on increasing heat gain during winter hours from sunrise to sunset. This would be one of those particular conditions that work against passively moderating thermal comfort during colder periods.

For the matter of glazing considerations based on the previous tables it can be concluded that insulated clear glass without reflective film, but with low-e coating is a good balance. It affords heat loss reduction from insulating qualities while allowing higher amounts of solar heat gain and minimizes harmful ultraviolet rays from entering the office space. Lastly, this option also allows for more daylighting due to the increased light transmittance. Also, similar to the recent retrofit of the Empire State Building in New York, although admittedly not a low-rise office, Johnson Controls Inc. "...added Mylar sheathes between glass window panes and resealed existing windows for energy savings" (Gelfand et al. 2012).[107] Accordingly, manipulating existing glazing may be a viable option. This is the case so long as the glazing is properly shaded during the summer. Surely there is a tradeoff here, but low-emissivity coatings work favorably for

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[106] "Solar Energy Materials and Solar Cells," (Uppsala, Sweeden: Elsevier B.V., 2007) http://www.sciencedirect.com/science/article/pii/S0927024806004570 (accessed April 5, 2012).
[107] Gelfand and Duncan, *Sustainable Renovation Strategies,* 87.

the New York Metro area. This combined strategy is also recognized by architects who specialize in modern facade retrofit projects. According to design professionals, "a better understanding of the local climate offers improved thermal management and replacing existing insulated glass panels with new high efficiency insulated glazing, combined with approaches to sun-shading, passive heating, insulation and air infiltration can bring back the original intent for daylighting in late modern buildings" (Gelfand et al. 2012).[108]

Considering this particular type of window would be more efficient on a primarily southern exposure it also performs well for other exposures. For more northerly exposures that receive little to no direct sunlight, low-e glazing becomes necessary at minimizing heat loss. Also, for these exposures it is recommended that glazing also be clear so long as privacy during the day is not of major concern. According to previously discussed climate data, this should be the case in an effort to avail the largest daylighting factor for overcast or diffuse sky conditions. This will also be proven in the design phase of this project.

[108] Gelfand and Duncan, *Sustainable Renovation Strategies,* 101.

Other Factors

pp 85-86

Glazing and Daylighting Factors:

The building envelope, including window frames and connections should be sealed while allowing for passive and active air changes as required. Average estimates of infiltration associated with heat loss per square foot (SF) is considered high for glass curtain wall systems as they have more seals.[109] "Office buildings typically experience a loss of -0.09 Btu/Hour per SF and in some cases as much as -0.15 Btu/Hour per SF" (Brown et al. 2001).[110] A building's construction, microclimate, weatherproofing in addition to poor envelope seals can compound this deficiency. While air infiltration reduction is important, it will not be of further study as the subject building will be assumed tightly sealed. This will therefore alleviate another complex variable from this research project. Focus will be respective of glazing factors for both heat absorbing glass, non-heat absorbing glass, framing factors (ratio of glass to framing) and the consideration of clean glass in a vertical orientation. Glazing dirt factors can be seen in Table 8.[111] This information will need to be considered for environmental analysis settings, which will be discussed in the design phase of this project.

Table 8: Glazing Dirt Factors
Source: Krishan et al. 2001

Location	*Vertical*	*Sloping*	*Horizontal*
Clean	0.9	0.8	0.7
Industrial	0.7	0.6	0.5
Very dirty	0.6	0.5	0.4

[109] Brown and Dekay, *Sun, Wind & Light*, 51.
[110] Ibid.
[111] Krishan, Baker, Yannas, and Szokolay, *Climate Responsive Architecture*, 139.

Computer Aided Modeling and Analysis

pp 87-90

Autodesk Ecotect, Revit Architecture and Vasari Wind Tunnel Analysis:

The computer aided modeling and environmental analysis software Autodesk Ecotect 2011 (Ecotect) shall be used. The methodology of studying a singular open office building without furniture promotes a stronger, more universal conclusion for daylighting, solar radiation and wind-tunnel analysis. The appropriate studies of daylighting protractors in addition to material reflectance and light diffusion principles are already embedded into this program.[112] This implys that illuminance and shading levels can be determined for an entire building, based on a users input. According to a basic understanding of how existing building design analysis works, "it requires an element of diagnostic thinking, often starting with figuring out how the building was meant to work when it was originally built" (Gelfand et al. 2012).[113]

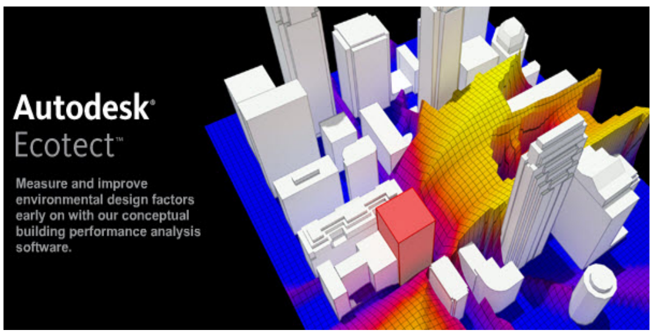

Figure 38: Autodesk Ecotect Promotional Image
Source: Autodesk 2010.

Solar radiation, angles of incidence, sun-path, percentages of unobstructed sky, diffused light values, in addition to a multitude of other passive design subjects are also included in the software. Ecotect gains its weather file information from the United States Department of Energy (USDOE) and the Energy Information Administration (EIA). This data can be considered current and reliable as weather files are loaded into the program directly from governmental agencies. After conducting an environmental analysis, "one

[112] "Ecotect Analysis Sky Illuminance," Autodesk, Inc., last modified January 15th, 2013 http://wiki.naturalfrequency.com/wiki/Sky_Illuminance.
[113] Gelfand and Duncan, *Sustainable Renovation Strategies,* 144.

can study the results in multiple ways as it can be used to generate and test passive design and renewable energy strategies" (Hootman 2013).[114]

Computer aided analysis will be shown in axonometric, section, elevation, plan, table, chart, graph and in the form of percentages of improvement over an analysis grid. Ecotect also offers the ability to input projected utility costs and using its automated calculation abilities one can also determine greenhouse gas emission reduction. It also allows a designer to quickly hypothesize and then test a design scenario, over and over again. This enables the designer to capture the effects from making minimal changes to the building model. Lastly, Ecotect offers near actual environmental conditions based on yearly, daily and hourly averages, as manipulated by the user. [115]

Although this software has many advantages, it also has disadvantages as recognized when using it for the design phase of this project. For instance, the software is limited to how much detail the user can input to the building model. This is in the sense where Ecotect slows down to considerably low speeds of analysis when it contains more information. Therefore, building models need to be scaled down from their actual intricacy so that more expedited calculations can take place. Common things like applying many window mullions and overlaying wall materials in layers is not suggested. This software platform seems to prefer 2-dimensional surface modeling measures that are simple to understand whereby one surface represents the makeup of many. For instance, a wall cavity made up of glazing with rigid foam insulation and interior steel furring with gypsum board would be calculated as one combined material by using the combined thermal resistance value. As a matter of fact, the building model that was used for final

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[114] Hootman, *Net Zero Energy Design*, XVI-XIX.
[115] Autodesk Ecotect Analysis 2011 (Version 5) [Software]. Available from http://usa.autodesk.com/adsk/servlet/download/item?id=13140033&siteID=123112.

simulation needed to be redrawn four times over before the software responded quicker and more accurately. For these reasons, complex building models may be difficult to study. It is therefore important to analyze a building with simplified geometries and have material resistance, reflectance and conductance values on hand.

The input and modeling method used for wind tunnel analysis will be derived from a compatible building information modeling (BIM) program, namely Autodesk Revit Architecture 2011 (Revit). This software can be considered a horizontal platform by which transitioning between Vasari wind tunnel modeling and Ecotect is made easy[116]. Modeling will be done in zones which can later be recognized and analyzed by Ecotect. These platforms allow existing buildings to be studied as well as the proposed retrofit. If necessary, Revit is also suitable for photorealistic rendering production to prove that aesthetics will not be hindered by incorporating the proposed retrofit. Likewise, the combination of software and plug-ins shown in Figure 39 are complete for environmental analysis and makes for a professional project display when finished. [117]

Autodesk Ecotect 2011: Environmental Analysis

Desktop Radiance 2.0 Plug-in: Photometric Rendering

AutoCAD Architecture 2013: Details

Vasari Beta 2.0 2013: Wind Tunnel Analysis

Revit Architecture 2013- 3D Modeling

Figure 39: Combination of Software Programs Used for Environmental Analysis
Source: Autodesk 2010, Autodesk 2013, Radiance 2002.

[116] Autodesk Vasari Beta 2, 2013 [Software]. Available from http://autodeskvasari.com/VasariBeta2.
[117] Desktop Radiance 2.0, 2002 (Beta) [Software]. Available from http://radsite.lbl.gov/deskrad/download.htm

Solutions

pp 91-93

Economy, Efficiency and Occupant Comfort:

The overall goal is to provide an economical retrofit design strategy which cools and daylights during warmer periods and vice versa. The solution must also be one that simultaneously promotes passive ventilation and views that reduce or eliminate glare. A comprehensive passive design technique is necessary to mediate these variations. The building envelope retrofit strategy should be used as a moderator, similar to the task of a referee, but in this case between the interior and exterior. For this reason, operable retrofit devices will be compared by their ability to control thermal and occupant comfort. Only after, should they be assessed for feasibility and cost.

Based on research and other self-studying methods, this project stands to suggest an idealized operable passive design typology of a 3-dimensional rhombus (Figure 36). This shape should incorporate the passive design strategies regarding ventilation, shading, daylighting and solar radiation while maintaining views, eliminating glare and responding to micro and macro environmental conditions. This can be achieved by using an operable louver device with both horizontal and vertically slanted fins that can move in and out of a building envelope. This offers the flexibility of rotation to respond to varying climate conditions. The idealized retrofit should also operate by automated motor/control devices; using indoor and outdoor measurements of wind velocity, air temperature, illumination, and humidity and minimize infiltration. Lastly, the proposed retrofit must be economical and feasible to install within an existing low-rise open office building glass curtain wall framework as this will be the controlling factor to how this retrofit may take place.

Recent remedies for replacing outdated and aging curtain wall systems stand to suggest thermally broken aluminum frames and multi-pane glazing to eliminate thermal bridging problems and condensation issues.[118] This is aimed at breaking existing thermal bridges which are "highly conductive building envelope construction elements that bypass insulation and act as a short circuit" (Tuluca 1997).[119] While this will minimize conduction issues for late-modern aluminum curtain wall systems, it can be considered uneconomical if an existing building facade framework is still in good condition. All research previously conducted is regarding a *best-case* retrofit design scenario for the MLOOB envelope in the New York Metro area. This will be further studied with additional variations and comparisons in the design phase of this project.

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[118] Gelfand and Duncan, *Sustainable Renovation Strategies,* 93.
[119] Tuluca, *Energy Efficient Design*, 7.

Research Project Findings

pp 94-96

A Synergistic Retrofit Approach is Key

Reduction in energy use, cost savings and pollution are all relevant to designing an energy efficient building envelope retrofit. Findings on specific typologies were discussed in the body of this research and collectively make up the thought process one should take when proposing passive solar radiation, shading, daylighting and natural ventilation strategies for the modern low-rise open office building. The overall process should not be handled as an independent subject for each strategy, rather it should be combined.

Building designers should focus more effort towards measures that have respect to the climate. As provided, it is clear there are numerous energy conservation opportunities for the designer to consider that promote energy cost savings while positively affecting the environment. These measures require respect for the natural elements of the sun, wind, water, air temperature and weather patterns that affect buildings and ultimately occupant comfort. It is important to again emphasize that the modern low-rise open office building facade may be redesigned for better efficiency. When done correctly, it can also maintain the overall form and function of this building typology.

To passively retrofit a low-rise open office building envelope in the NY Metro area is to consider occupant comfort, weather, time of day/year, passive design typologies as well as the environment, energy use, economics, feasibility, structures and aesthetics simultaneously. According to design professionals, "Light and energy that passes (or lack thereof) through the building envelope creates the need for artificial lighting and mechanical systems and changes the performance of the building envelope; potentially making it unnecessary to upgrade them. If the building envelope is part of the scope of work of a renovation, it can create a major opportunity" (Gelfand et al. 2012).[120] As a direct result of such considerations, there may also be less maintenance, repair and replacement of related building systems that would otherwise operate for longer durations.

By triangulating all of these subjects one has the ability to promote energy savings in a multitude of ways. Synergistic passive design approaches respecting climate conditions as well as other micro and macro-environmental concerns provide the best solution. As mentioned earlier, the ideal passive design retrofit strategy as determined uses a set of rotatable vertical and horizontal louvers that are constrained within the form of a 3-dimensional rhombus; maintaining views and natural ventilation through awning windows (Figure 35 and 36).

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[120] Gelfand and Duncan, *Sustainable Renovation Strategies,* 38.

Design Project Introduction

pp 97-101

Existing Building Information: The Towers

The office building chosen for the design phase of this research project is located in the northwestern portion of Long Island and is currently known as *The Towers*. It resides within an upscale suburban community and was developed on Great Neck Road in Great Neck Village, NY. It is part of a mixed-use commercial zoning district and is adjacent to other office, condominium and apartment buildings. While the Towers was initially designed as an open office, it has since been repurposed to have individualized spaces for its tenants.[121] For this design project, subdivided spaces have been intentionally omitted for clarity and timely environmental analysis. Building core areas have also been omitted from natural daylighting and ventilation studies (to follow) as they are inner spaces and would provide nil analysis results. Despite these omissions, the Towers serve as a prime candidate to study environmental analysis; fitting the criteria of the symbolic modern low-rise open office building discussed in the research phase of this project. This building will also be used to test my hypothesis; increased solar radiation and natural ventilation will provide substantial energy use reduction.[122] Additional building and site information is bulleted below.

- Latitude: 40.8, longitude: -73.72.
- Section: 34, Block: 65, Lot: 7U.
- Building Fair Market Value (2013-2014): $23,598,000.
- Building orientation is approximately 45° clockwise from North.

[121] Field verification by author.
[122] Increased solar radiation may decrease energy use for heating during winter months and if the building is properly shaded during the summer; this affect may be compounding by reducing cooling requirements.

- Deciduous trees are parallel to building and approximately 45 feet high on

Southeast and Northwest exposures.

Property Manager and Great Neck Village Building Department Application:

- Jones Lang LaSalle, David Hercman, davidhercman@am.jll.com

  (unable to provide plans at time of visit, recommended building department).

- Village of Great Neck Plaza Application filed for Public Access to Records on July 7th, 2012 as Student, Representing the University of Hawaii at Manoa, School of Architecture at 2 Gussack Plaza, Great Neck, NY 11021.

Building Information Modeling Assumptions

For a more realistic study, the following assumptions have been made.

Occupancy: The building is occupied from 7:00am-6:00pm, with occupant usage ramping up and down based on the time of day and lunch hour. This information will prove useful for establishing latent heat gain from occupants and their activity (sedentary, 70 Watts per hour) throughout the course of a weekday. It is being used to establish more realistic heating and cooling loads in the building.

Human Clothing Factor: 1.0 used for purposes of simplicity, rather than calculating varying clothing insulation factors for each season. See Figure 6 in research project for more information.

Humidity (%): 60

HVAC Air Speed: 98.4 ft/min.

Artificial Lighting Level: 27.9 footcandles (fc), used for sensible heat gain assumption and daylighting comparisons.

Number of Occupants: 129 Square Feet (sf) / occupant (12m^2/occupant).

Internal Heat Gains: Sensible: 1.585 Btu/hr./$ft.^2$ Latent: 0.634 Btu/hr./ft^2

Air Infiltration Rate: 0.5 (assuming a well-sealed building, includes air exchange between zones and outside environment, based upon a Monday-Friday 7:00am-6:00pm occupant schedule).

Active Air Conditioning System: Mixed Mode, 95% Efficiency (providing heating and cooling).

Comfort Band: Lower: 64.4°F Upper: 78.8°F

(Environmental Temperature Range for Comfort and System)

Hours of HVAC Operation: Weekdays 7:00am-6:00pm, Weekends: 8:00am-12:00pm

Zone Volume Calculation: Medium Precision

Calculated Information for Zones Receiving Retrofit:

Zone: 2nd-6th floors, Total Floor Area: 107296.86 ft2, Volume: 1288775.62 ft3

Solar Access Analysis (used for Solar Radiation Studies):

Solar radiation calculations use hourly recorded direct and diffuse radiation data from the weather file and rely upon material specifications. Overshadowing and shading calculations have been automatically calculated by Ecotect with medium precision and are assumed to be correct. The time range as studied is between 7:00am-6:00pm from June 6th-September 10th and represent cumulative averages upon surfaces that have been modeled.

Daylighting Analysis:

Shows natural light levels at specific points in the model. "Natural light levels are not date or time dependant - they represent worst-case design conditions based on an *average* uniform sky distribution in mid-winter. Calculations are based on the BRE Split Flux Method which uses daylight factors and the design sky illuminance value (603.9 fc, derived from model latitude) to determine with medium ray-tracing precision, likely natural light levels in the model across the analysis grid" (Autodesk 2013). [123] This method is also taking into account an increased accuracy mode which considers the transparency and refractive index of window glazing and actual surface reflectance of external objects. This study assumes a window cleanliness factor of 0.9 (average) as Autodesk Ecotect 2011 requires the user to select one and a regular buildup of dirt is expected.

Specifications:

Light reflectance values for acoustical ceiling tiles and white light shelves are 0.9 (white/high) and pertain to specifications from each manufacturer. Carpeted floor light reflectance values were chosen as 0.3 (dark/low) as they are assumed to be of darker color for open office spaces with daily foot-traffic. A maximum of three reflections has been set and pertains to daylighting studies. Daylight is expected to reflect off of the light shelves, to the ceiling, then down to the floor and back up again with any remaining reflection. Accordingly, natural lighting analysis decreases in this manner for the existing building and with the proposed retrofit.

[123] "Ecotect Analysis Sky Illuminance," Autodesk, Inc., last modified January 15th, 2013 http://wiki.naturalfrequency.com/wiki/Sky_Illuminance.

Site Analysis Photos

pp 102-105

Site Maps, Satellite Imagery and Site Photographs

The following maps and satellite imagery (Figure 40) show the building's location as a series of images that zoom closer to the project site. Starting from the North America (1), to the northeast region (2), to the northwest part of Long Island (3), to a portion of the City of Great Neck (4), then to the street (5) and lastly the project site (6).

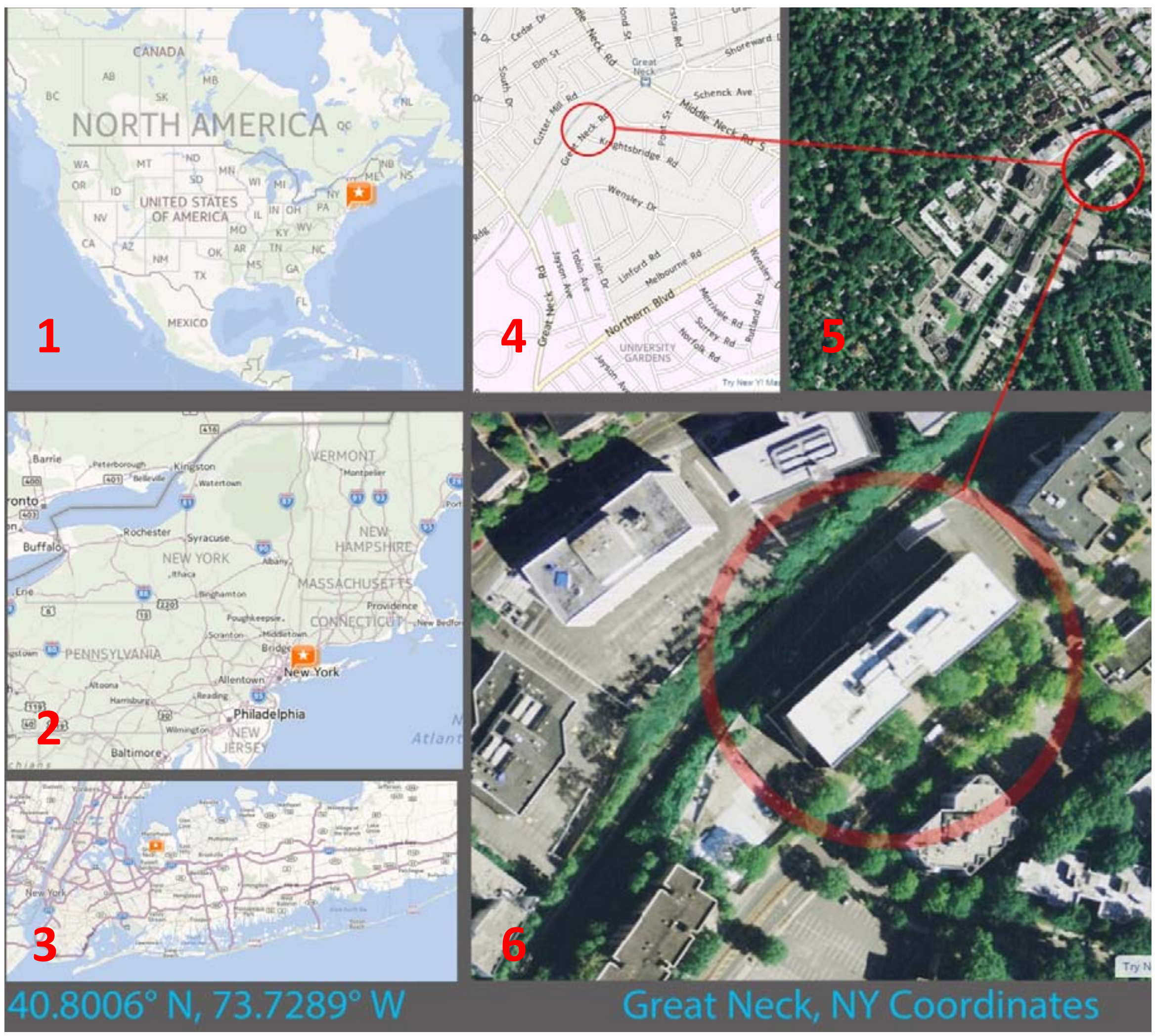

Figure 40: Site Map and Satellite Imagery
Sources: Yahoo Maps, Google Maps

The following bird's eye-view (Figure 41) shows the building's location nearly 45° clockwise from North, placed south of the Long Island Railroad track. The project location is within a mixed use zoning district and has a good buffer from other low-rise office buildings, condominiums and apartment complexes. As depicted in this image, most trees that surround the site appear to be tall and have large dark green leaf canopies that cast shade which almost reaches the building envelope.[124]

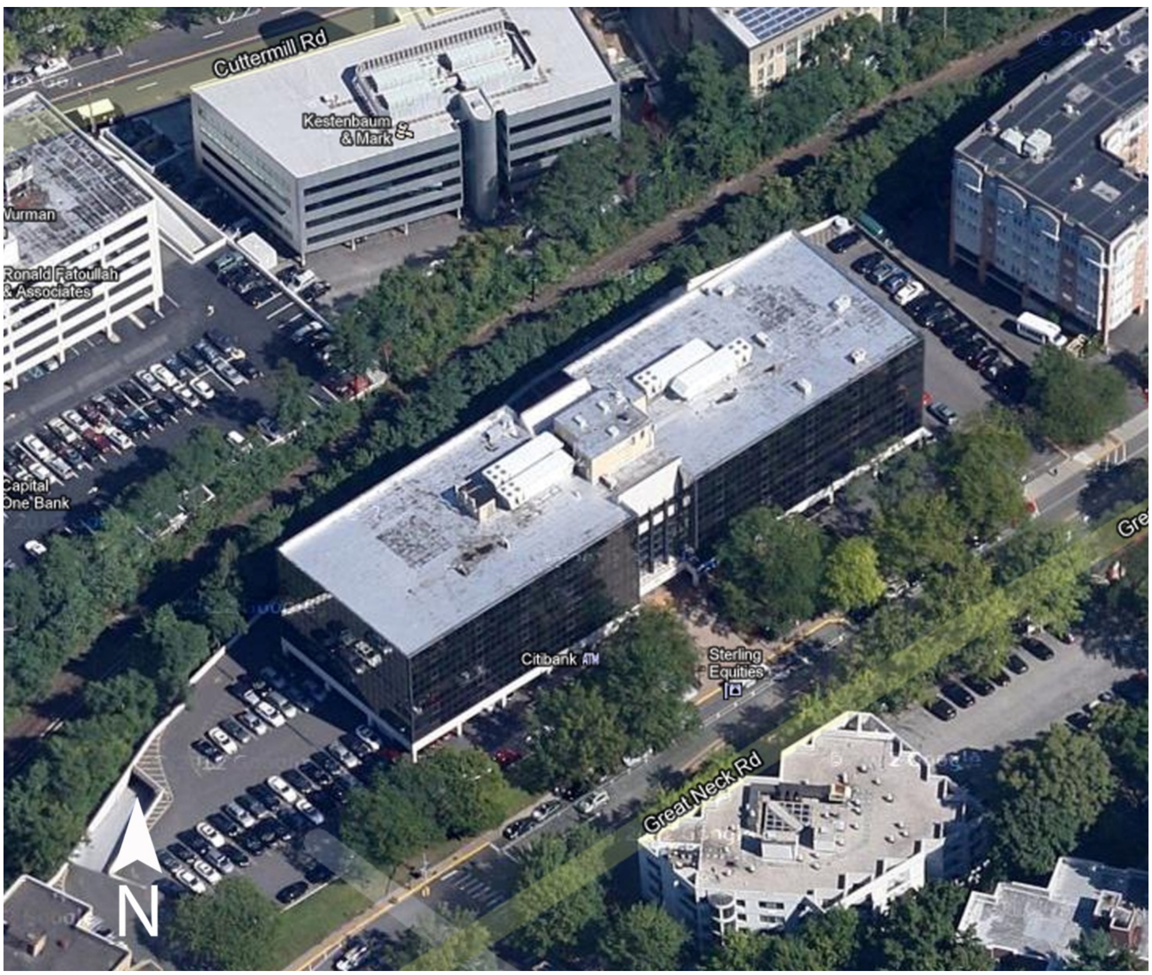

Figure 41: North Axonometric Birds-eye View
Source: Google Maps 2012.

[124] Google Maps Satellite View "100 Great Neck Rd., Great Neck, NY," accessed January 10th, 2013.

Figure 42 shows wide angle site photos taken on January 7th, 2013 at 9:15am. Since the site is now surrounded by trees without leaves, we know they are deciduous. Having this in mind, there will be minimal shading from the surrounding landscape during the winter. This allows for more daylighting and potential for increased solar radiation. These images also depict a workday hour when noticing the amount of cars parked above grade.

Figure 42: Wide Angle Site Photos
Photos by Author, Taken January 7, 2013 at 9:15am

Existing Building Analysis

pp 106-113

Type, Size, Function and Materiality

Type: Modern, 6 story (low-rise)**.**

Architect of Record: Blum and Nerzig Architects, 1978.

Year Built: 1980.

Function: Office Building

Size: Approximately 107,000 Square Feet (floors 2-6). First floor purposely omitted due to floor to ceiling frameless glass and masonry facade which is set back under 2nd floor slab (fully shaded).

Structure: Reinforced concrete column and slab.

Façade: Curtain-wall glazing and limestone.

Primary Question for Purposes of Design Project Study: Can building energy efficiency and occupant comfort be improved with a retrofit design strategy which is more based on the climate?

Existing Building Design Strategies Called into Question:

Are there energy efficiency and occupant comfort issues related to having highly reflective/ tinted glazing and the facade not being shaded? Substantial heat loss/gain is assumed to be due to the large area of windows on all facades, can this be improved to reduce energy loss? The building is not currently utilizing natural ventilation; could this feature prove useful to conserve energy use and improve occupant comfort?

Construction Plans and Building Photographs

As gathered on July 25th, 2012 from the Village of Great Neck Building Department, the following building plans in Figure 43 are shown. These images were obtained by filling out a Freedom of Information File Application on July 23rd, 2012 and represent the "Issued for Construction Set" dating back to 1978. Plans, elevations, cross-sections and building envelope details are shown and will be used for future design project analysis. To follow, Figures 44 through 48 depict existing building exterior and interior photos taken in January and July.

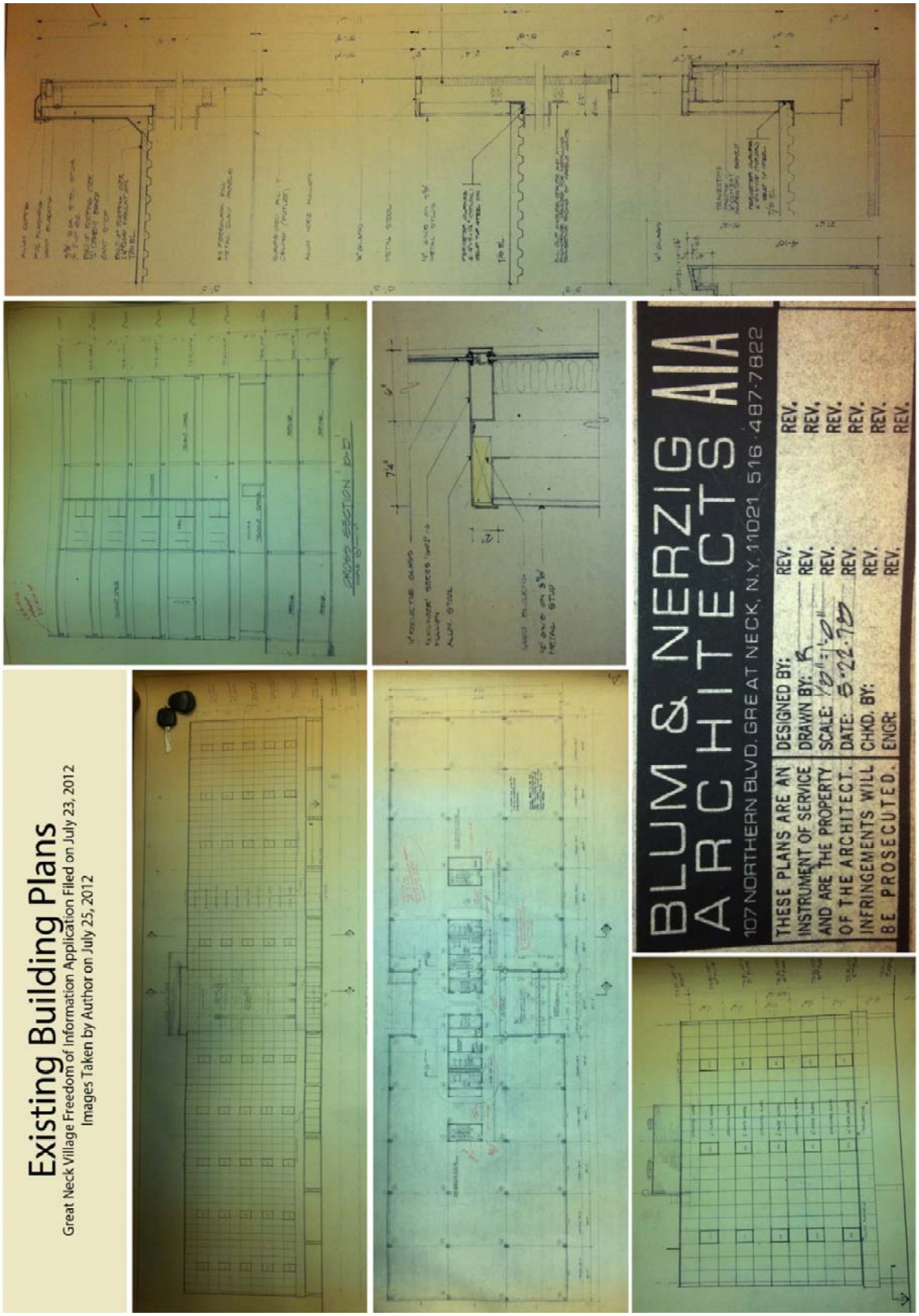

Figure 43: Existing Building Plans

Figure 44: Lobby and Exterior Photos

Figure 45: Lobby and Exterior Photos

Figure 46: Interior Building Photographs 1 and 2 Viewing Southeast
Photos by Author, Taken July 22, 2012 at 2:00pm.
Permission Received from Property Manager.

Figure 47: Interior Building Photograph 3 Viewing Southeast
Photos by Author, Taken July 22, 2012 at 2:00pm.
Permission Received from Property Manager.

Figure 48: Interior Building Envelope Photographs 4 and 5
Photos by Author, Taken July 22, 2012 at 2:00pm.
Permission Received from Property Manager.

Descriptions of Photos 1-5 (Figures 46 through 48):

Photos 1-5 depict the office interior viewing southeast through the curtain-wall glazing system at approximately 2:00pm on July 22nd, 2012.

In **Photo 1 (Figure 46)**, notice the recessed 2'x4' fluorescent light fixtures are off and the space is dimly lit by natural daylight. Horizontal blinds seem to be used to block glare as privacy during the day is not a concern with dark tinted windows.

When compared with **Photo 2 in Figure 46** we can see that these light fixtures are on and are directly adjacent to the existing glass and aluminum mullion facade. In this instance, artificial light is being used improperly as it should be shut-off with such ample diffuse and direct daylight available.

Photo 3 (Figure 47) reinforces this concept and is a good representation of how tinted glass windows skew the exterior colors of an outdoor environment (the colors should be more vibrant in July). Also notice the reflection of artificial light back to the occupant from the window reflections.

Photos 4 and 5 (Figure 48) show close-ups of typical window sill and head conditions. Notice the design strategy of directly abutting the sill slab (at 30" above finished floor) to the top of the lower window mullion face for an almost seamless, frameless glass appeal. Similar conditions occur where acoustical ceiling tiles run flush into the bottom face of the upper window mullions. These existing conditions are important to take note of and make for the subjects of how one could economically move forward with a retrofit, without having to redo ceilings or sills on every floor.

Environmental Analysis of Climate: Sun, Wind, Light, Temperature Data

pp 114-129

Sun Angles and Azimuth

The annual sun-path in Figure 49 represents the existing building's orientation with respect to a ground-plane compass. This figure illustrates the stark difference in sun angles from summer to winter (72° versus 26°). It also shows the azimuth as arch-bandings of lines indicating the suns' movements throughout the year. For instance, one can notice that during the winter periods the sun is out for shorter durations each day when compared with the summer. This can be determined by analyzing arch-band lengths (in blue) between seasons. All future shading, daylighting and solar radiation calculations will be based upon this sun path and the solar angles as determined from 7:00am-6:00pm workday.

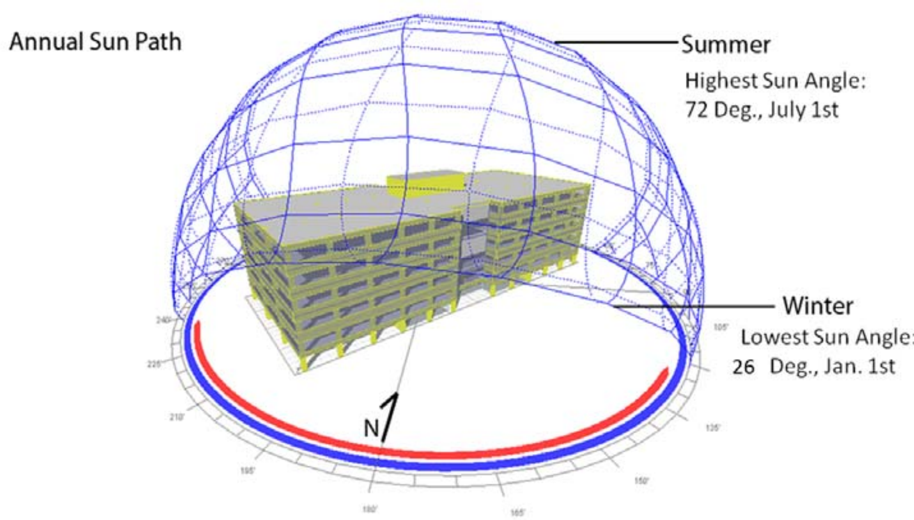

Figure 49: Annual Sun Path Perspective Viewing North
Source: Ecotect Analysis 2011, Diagram Generated by Author.

Heating and Cooling Degree Days

As shown in the standard Monthly Degree Day Graph, Figure 50, the blue bars represent times of the year when heating is required whereas the red bars are when cooling is required. The higher the quantity of degree days means the larger the intensity of energy demands. The overall goal for the building designer is to neutralize these fluctuations with the use of passive and/or active air conditioning systems. In this design project, passive design strategies will move to the forefront with remaining differences to be maintained by active mixed-mode (heating and cooling) HVAC systems.

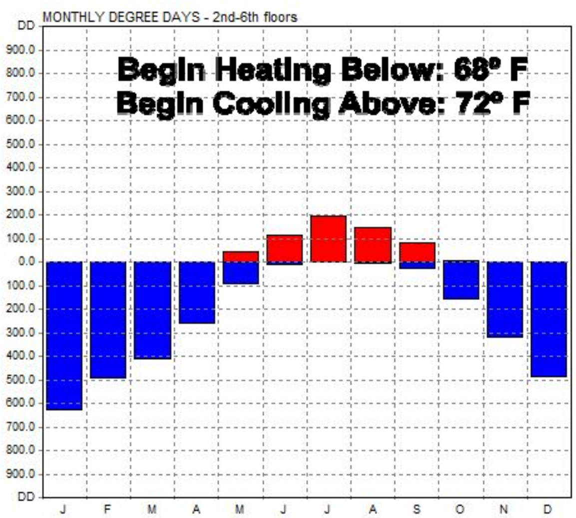

Figure 50: Standard Monthly Heating (Blue) and Cooling (Red) Degree Days Chart
Source: Ecotect Analysis 2011,
Diagram Generated by Author.

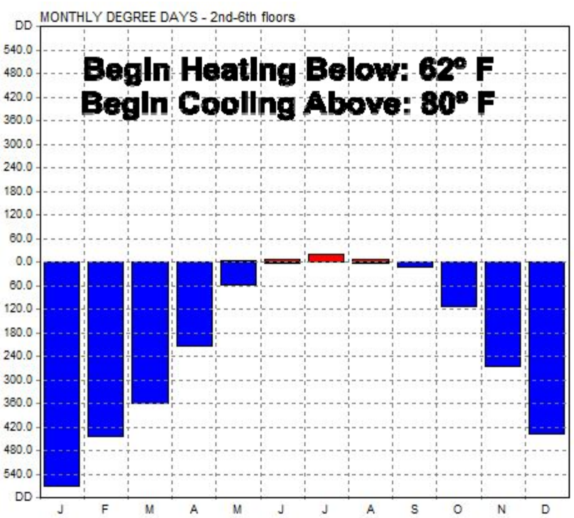

Figure 50.1: Adjusted Monthly Heating (Blue) and Cooling (Red) Degree Days Chart
Source: Ecotect Analysis 2011,
Diagram Generated by Author.

As generated from Ecotect, Figure 50 is similar to the standard monthly heating (HDD) and cooling degree days (CDD) calculations as noted in the research phase of this project. This assumes a HDD and CDD baseline of 65° F when calculating totals. Assuming building occupants are capable of maintaining their own thermal comfort when outdoor air temperatures are between 62° F and 80° F (see research Figure 8), this chart will adjust. This means the adjusted HDD calculation would use 62° F as a lower baseline and the adjusted CDD calculation uses 80° F as an upper baseline (see Equation 2 for more information). This variation is captured when comparing Figure 50 (standard) to Figure 50.1 (adjusted) degree day charts. Since both figures are solely based on the climate they do not include internal office variables; heat gain, lighting, computer equipment, the quantities of occupants and their activities. Although separate, it does go to mention that these are still important factors to consider. In summary, heating requirements demand far more energy than cooling requirements assuming the building occupants can use the passive zone temperatures to their advantage. This can be considered a general rule of thumb for this project and any modern low-rise open office building in the New York Metro area.

Wind Rose and Tunnel Analysis

Figure 51 shows the nearest weather station being used for Autodesk Ecotect Vasari Wind Tunnel and Wind Rose analysis. Vasari is a separate platform created by Autodesk, Inc. and is currently in the Beta (testing) stage of production.[125] This weather simulation software is useful to estimate interior wind velocities based on outdoor prevailing winds and window opening (void) percentages.

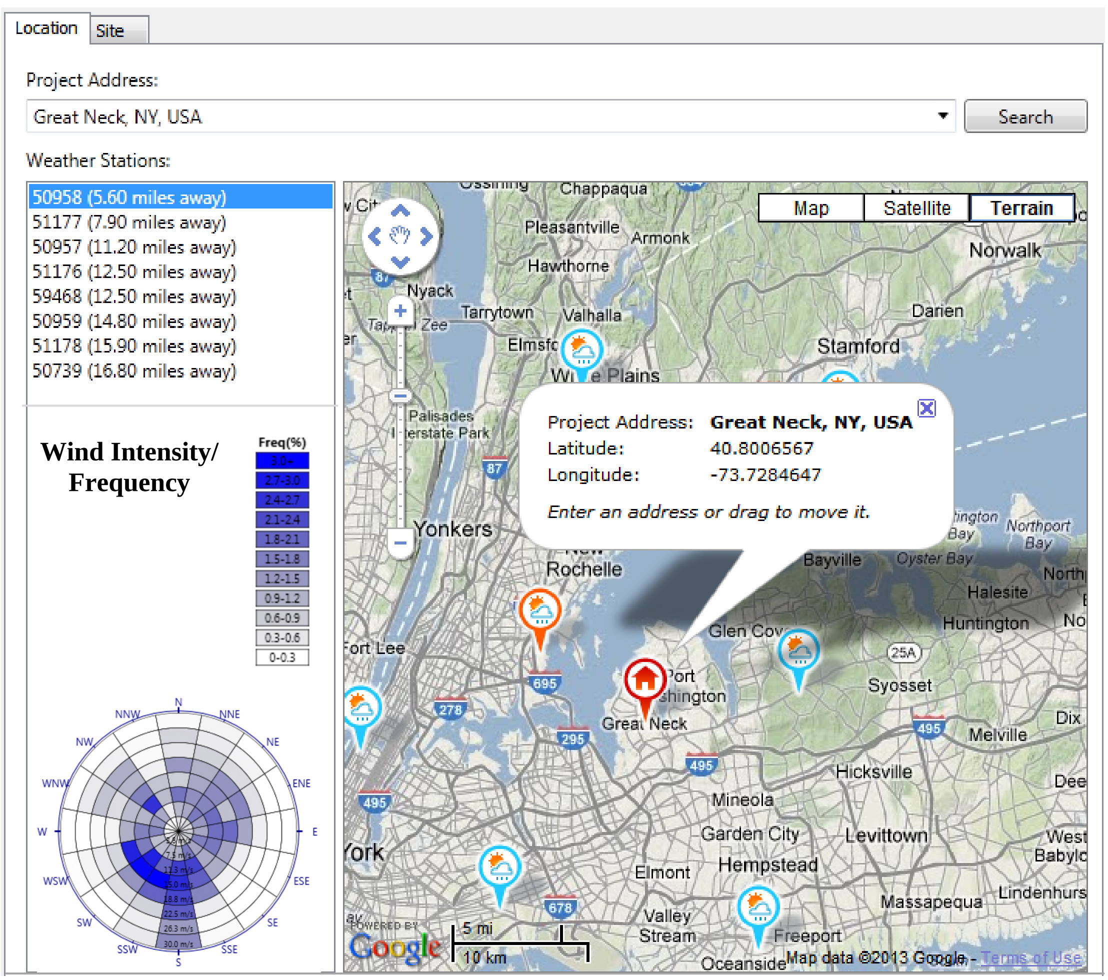

Figure 51: Weather Station Location and Prevailing Wind Intensity/ Frequency Compass
Source: Autodesk Vasari Beta 2.0, Diagram Generated by Author.

[125] Autodesk Vasari Beta 2, 2013 [Software]. Available from http://autodeskvasari.com/VasariBeta2.

The Wind Rose Maps shown in Figure 52 indicate wind intensities and durations with respect to the compass direction (North is up). This information can be used to

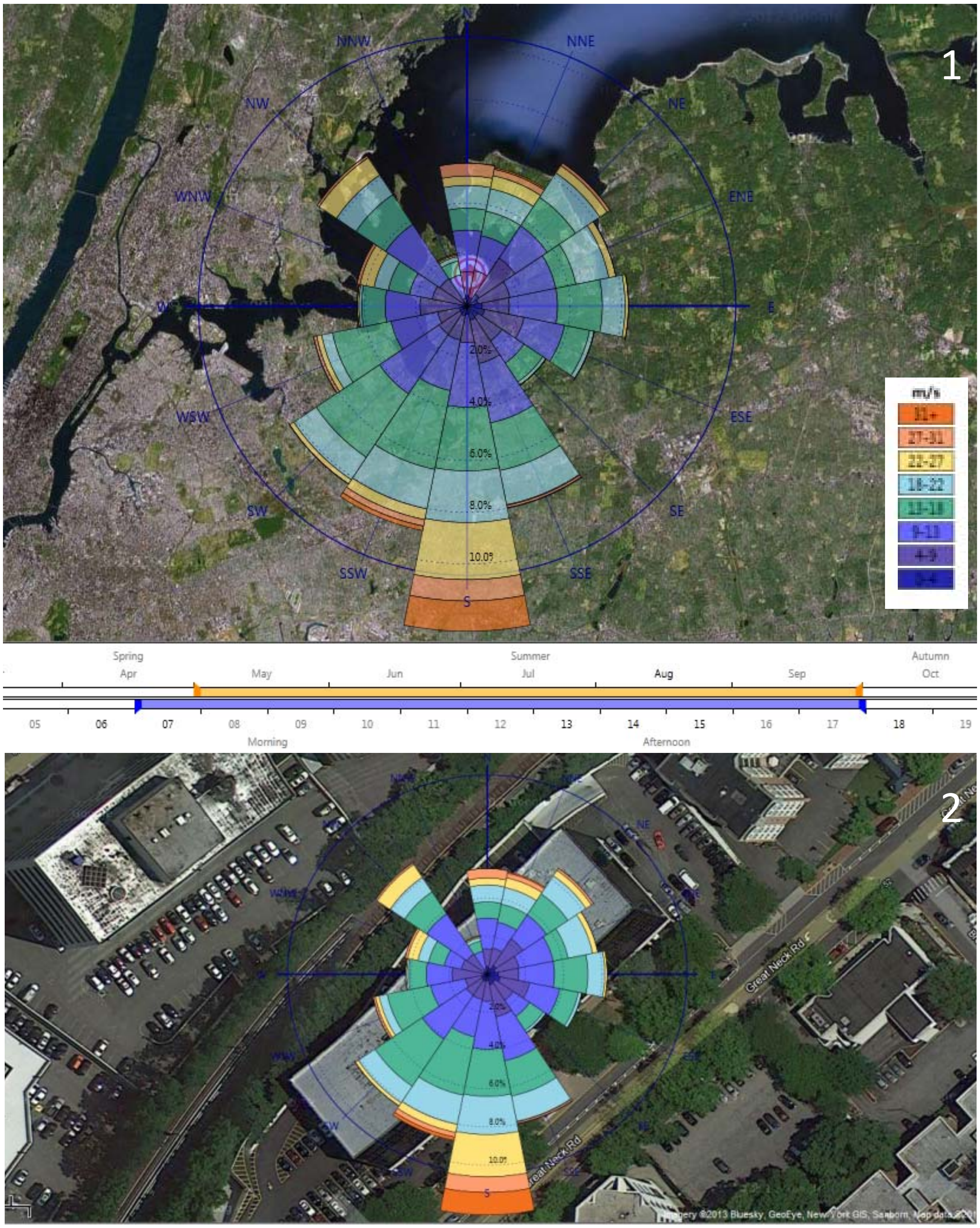

Figure 52: Workday Prevailing Wind Direction and Intensity Overlays 1 and 2 from May Through September, 7:00am-6:00pm
Source: Autodesk Vasari Beta 2.0, Diagrams Generated by Author.

determine wind intensity data as indicated by the 24-hour period and months shown. When referring back to previous research regarding temperature records one will find that outdoor air temperatures within the *passive zone* fall between the months of May through September. Including building operating hours (7:00am-6:00pm M-F, 8:00am-12:00noon weekends), one can determine when natural ventilation can be used passively. In the case of this subject building, the months of May-September may allow an enhanced conservation of energy by using natural ventilation strategies. This is where the building designer can use directional wind-flows to their advantage by carrying desired outdoor air temperatures through the indoor air space. This strategy also allows for necessary fresh-air changes to occur, as required for occupant comfort.

Since building envelopes moderate between indoor and outdoor spaces, micro-environmental factors must also be accounted for. Bearing in mind the location of Great Neck Village, and in particular this building, outdoor noise and pollution dynamics should not be of major disadvantage. However, animals, insects and micro-organisms, including pollens, may be of concern. This is especially true since tall tree canopies are somewhat close (~30') to the exterior building facade. This is where window screens will come in handy and will be a required component of the retrofit strategy. While window screens and nearby tree canopies may have slight effects on fluid velocities, lowering wind speeds and slightly shifting their direction, for the purposes of this design project these components have been omitted (based on the limitations of Autodesk Vasari). Therefore, windows will be studied as voids within the building model facades. This type of study is only a "near approximation" of the consequences for the proposed retrofit in order to include measures for natural ventilation.

The Wind Rose Map, while a great tool, is an incomplete picture in regard to more accurate information available to the designer. One can further narrow the subject of prevailing wind directions by analyzing average values as trends across work days (Figure 53). This next step is an important component of this design project to see how varying wind conditions may affect building occupants. By studying wind to this level of detail helps bring this design project one step closer to reality. In doing so, one is able to correlate the following.

-when the sun is out; wind velocities are stronger,
-when the sun is overhead, wind velocities are more intense.

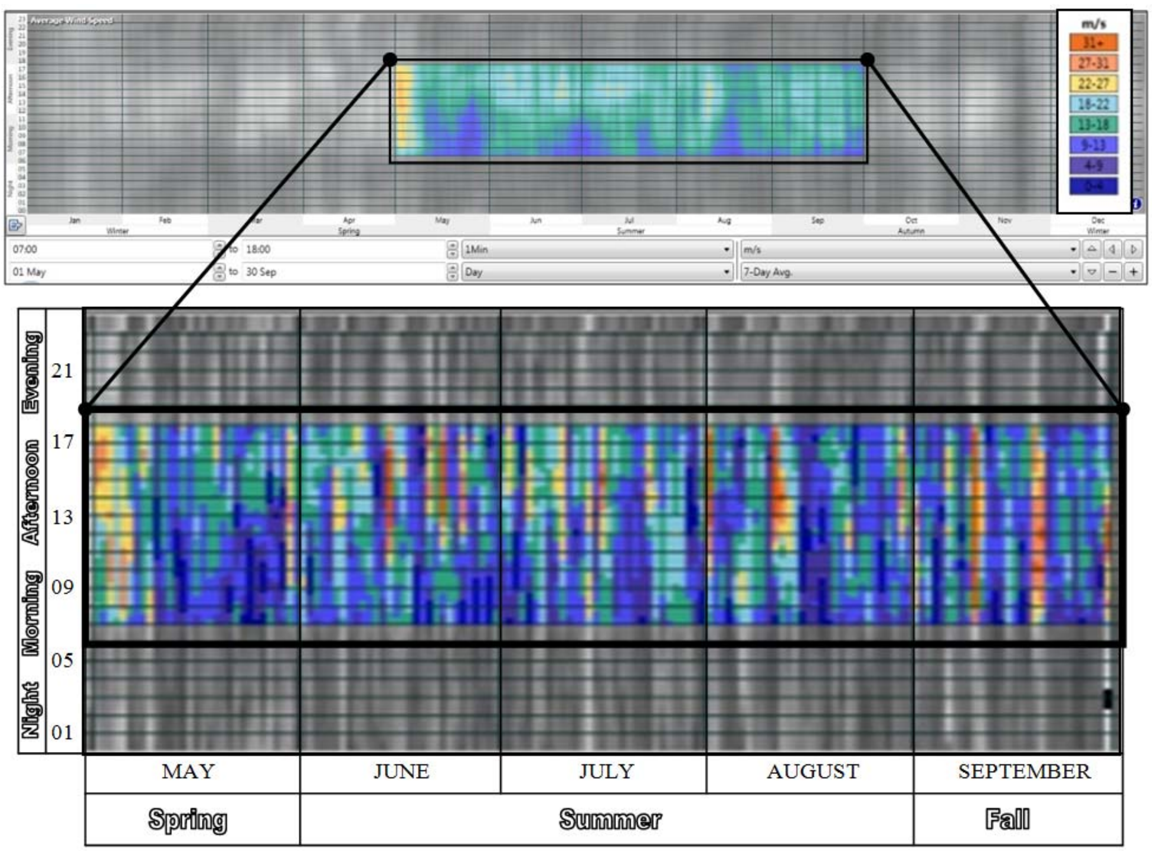

Figure 53: Workday Averages for Weekly, Daily and Hourly Wind Intensity (m/s) Durations from May Through September, 7:00am-6:00pm
Source: Autodesk Vasari Beta 2.0, Diagram Generated by Author.

Figure 53 substantiates this by higher prevailing wind velocities (lighter blue and green colors) erratically occurring between the hours of 12:00pm and 3:00pm. These findings also show that wind is working in our favor with respect to the time of the day; during warmer periods, when we need it most. It also goes to show that while prevailing winds are important to generalize wind conditions, this building will inevitably receive prevailing winds from all angles of the compass. This being the case, one can conclude that windows are necessary for all orientations, especially if one is to enable more user flexibility to control natural ventilation. Windows are also needed on all orientations for cross-ventilation because air pressures can build up, which may slow air flow. One additional piece of climate data is missing. One should also have an awareness of relative humidity during these same periods. This will help to estimate the quantities of days where one could use natural ventilation and relative humidity levels are ideal (less than 60%). This information will be calculated into the energy savings and comparison chapter to follow.

The proposed retrofit solution for natural ventilation will call for the addition of window mechanisms to make select existing windows operational. Location, sizing and quantities of windows have been included within the building model and are shown below with respect to a strong prevailing wind from the south (~20 mph). This strength of wind, although less common, gives a better understanding of fluid mechanics with exaggerated results (showing more intensity for visual understanding).[126] It has been assumed, with reasonable estimation through multiple wind tunnel studies, that the similar air movements will occur at slower wind speeds as all data are the same, without

[126] According to mean wind speed climate data figure 2.3 presented in the research phase of this project.

variables (other than velocity). Considering this assumption, one can appropriate the following conclusions in regard to Figure 54. The Tower's rectangular mass projection is northeast and at a diagonal to most of the winds received during the summer passive zone

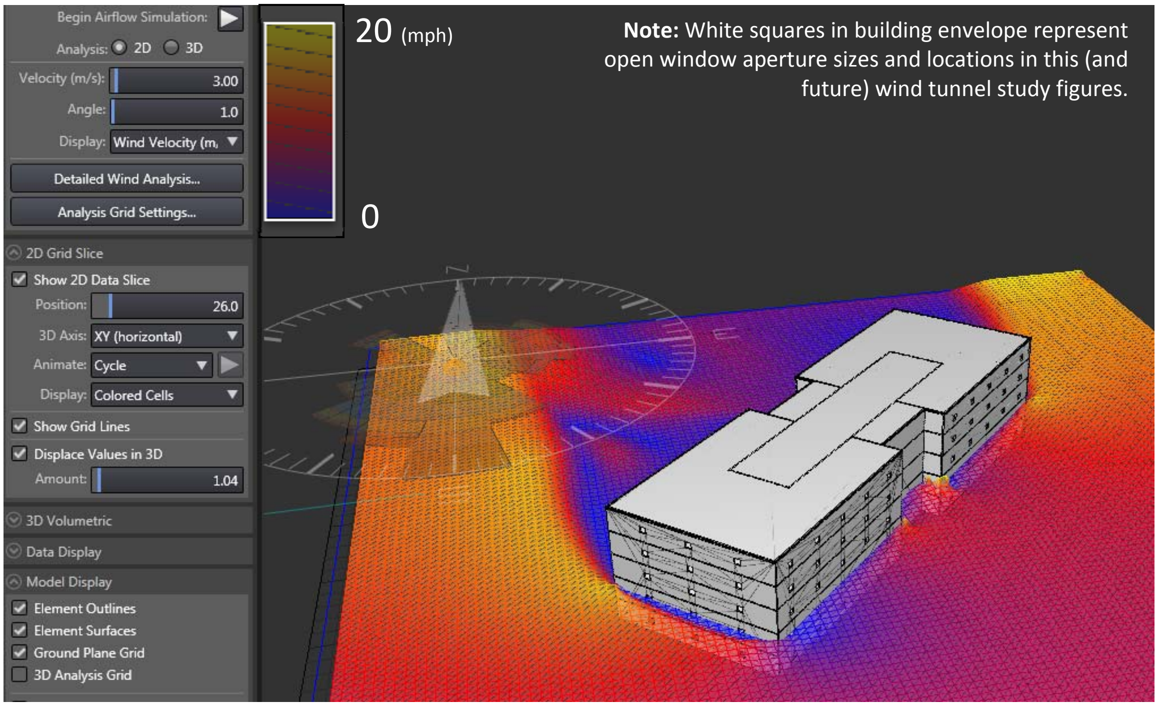

Figure 54: Axonometric Wind Tunnel Study (In mph)
26'-0" Above Grade With Prevailing Wind From South)
Sources: Autodesk Vasari Beta 2.0, Diagram Generated by Author.

workday (Figure 8). From this illustration one can note the direction and width of a wind shadow is slightly larger than the mass obstructing wind flow on the horizontal analysis grid-plane. It appears that air velocities increase along planar edges of objects in further downwind directions. As more wind is deflected and carried along this building's surfaces, fluid velocities increase, similar to the concept of pouring liquid into a funnel. In contrast to the previous note, lower air pressures may develop along immediate obstructing exposures and along opposite non-visible faces of the building model. Based on the fluid characteristics of this particular prevailing wind velocity (3 m/s), this image also suggests that a positive/negative vortex effect occurs beyond the building envelope. This can create a negative pressure that pulls wind through the office by cross ventilation.

These conditions may only be considered true in the horizontal plane at this particular elevation (26'-0" above grade) and shall not be considered a complete wind tunnel study by itself as it is only 2-dimensional. However, for the purposes of this design project, the amount of information found from this wind tunnel/building mass study is adequate to move forward. This information can now be used to correlate exterior wind flow with respect to the most important consideration; how air moves through this building's open office space, without furniture. Since south facade orientations are on the windward side and northerly facing building surfaces are leeward, interior office air will flow from high to low pressure in this same manner.[127]

Using similar conditions of southern prevailing winds, an interior wind tunnel study is helpful. Accordingly, Interior Wind Tunnel Study #1 (Figure 55) uses the window openings as shown in Figure 54 and below. This will serve as the primary mechanism to allow exterior airflow through the building envelope and into the office.

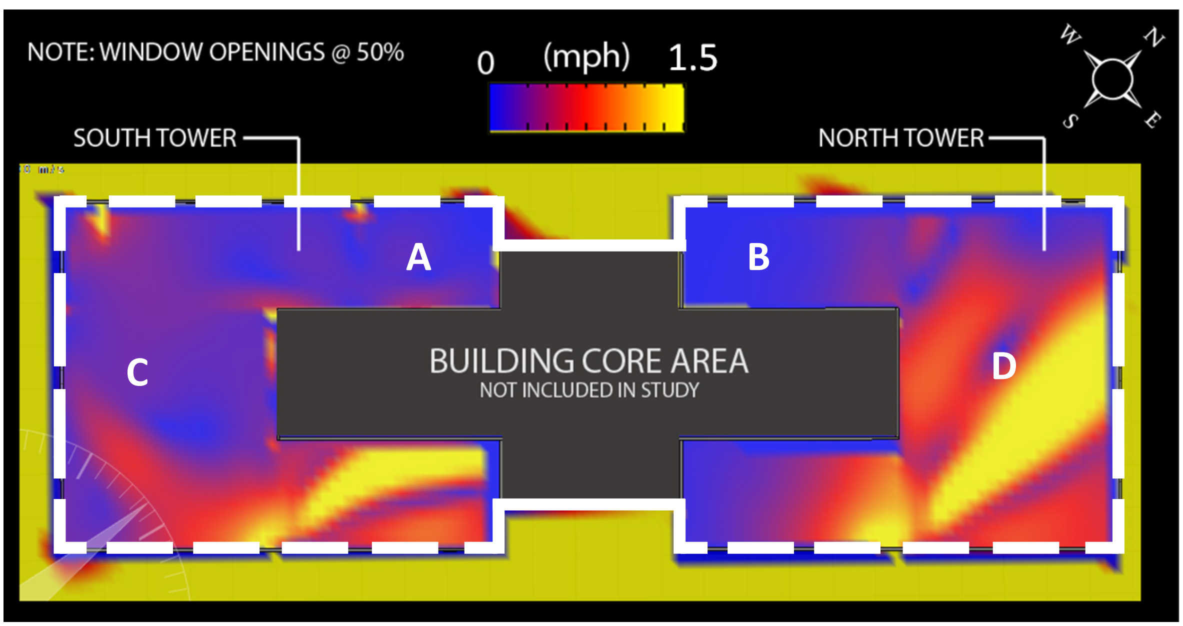

Figure 55: Interior Wind Tunnel Study #1 (Outside ~15mph Prevailing Wind From South)
Source: Autodesk Vasari Beta 2.0, Diagram Generated by Author.

[127] Gelfand and Duncan, *Sustainable Renovation Strategies,* 35.

The location of each operable window was chosen with respect to the existing curtain-wall system. The existing opportune locations are marked by the instance of a framed window within the curtain wall frame (FWF).[128] These subject window frames are currently in a fixed position and are therefore non-functional. It is assumed that with slight modification these existing FWF windows are capable of being removed and replaced with (3) equal window segments, working within the constraints of the light shelves to achieve natural ventilation. This process is also further substantiated as it is a known solution to "...replace large fixed glazing with new operable sashes and in buildings with energy management systems, windows can be controlled by small motors based on weather conditions" (Gelfand et al. 2012).[129] This can be done by adding industrial grade hinge points to the existing curtain wall system (see previous building interior photo #1 for condition), allowing crank-out operability from the facade.

As mentioned in the research phase of this project, window screens are required, but will not impede on the functionality of the proposed retrofit. To minimize the complexity of the interior wind tunnel study model these proposed window openings have been reduced from a 3'-6" x 5'-9" aperture down to a 3'-0" x 3'-0" opening (near 50% of actual size) and do not take sash angles into account. In other words, this interior wind tunnel study is only an approximation of the proposed retrofit strategy for natural ventilation, but it is one step closer to reality. For that matter, it can be considered night and day compared to studying prevailing wind directions without respect to the month of the year, day of the week, time of the workday, building surfaces, aperture sizes and opening percentages as this study aims to simplify. When correlating interior and exterior

[128] Similar to how a window frame is installed into a framed opening of a residence.
[129] Gelfand and Duncan, *Sustainable Renovation Strategies,* 122.

wind tunnel studies, one can see that the direction of an exterior prevailing wind direction is the same as the interior prevailing wind direction, assuming unobstructed openings. The major difference becomes how this air travels once it enters the open office space. Varying factors include interior wall locations; in this case the building core and adjacent curtain walls. For one, we can see that wind will travel around them and try to take the easiest way out. The path of highest office interior wind velocity occurs where fluid velocities combine. This can occur at wall surfaces, ceilings, floors and possibly in circulation aisles between furniture systems that have less points of air friction.

Similar to cross ventilation, this joining of air movements can work in the favor of the occupants so long it is in a controlled manner. The idea of introducing light-breeze to pass the occupants is the ideal scenario. From previous research, and as documented by ASHRAE standards, nearly a 1.8 mph wind passing across an occupant is significant enough to reduce a humans *real-feel* body temperature by nearly 5° F.[130] Now that a common goal is in mind, one should look to correct any conditions that may deviate from it. For instance, "wind-shadows" or areas having low-air movements may pose an issue. While this may be the case, these down-wind or more sheltered scenarios can be improved by occupant control. By this meaning wall obstructions which would otherwise defer interior air movements can be avoided by opening certain windows and closing others (due to pressure effects). This is shown with respect to interior wind tunnel Figures 55 and 56 with winds from the south and southwest. Notably, the northwest sides of the Building Core Area (A and B) represent areas where interior wind shadows occur. By using intuition as well as trial and error methods this air movement issue can be solved.

[130] "ANSI/ASHRAE Standard 55-2004," ASHRAE Inc., last modified 2004.

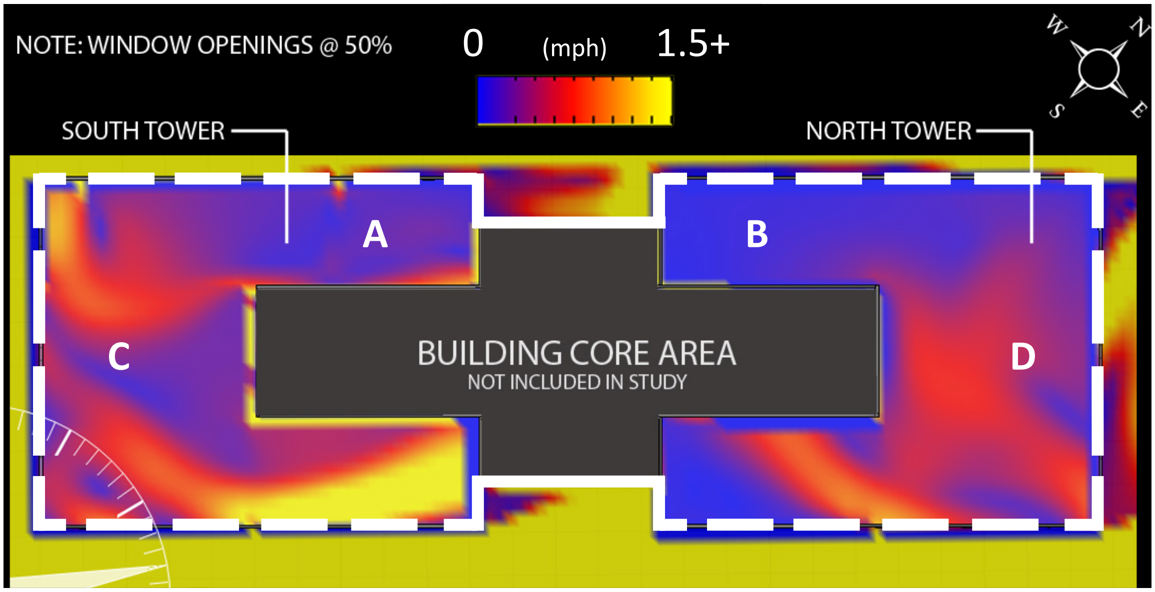

Figure 56: Interior Wind Tunnel Study #2
(Outside ~15mph Prevailing Wind From Southwest)
Source: Autodesk Vasari Beta 2.0, Diagram Generated by Author.

When looking back to the building plan, with respect to prevailing winds, such intuition strategies may include closing windows along the northeast facade and selectively keeping windows open along the northwest facade (North Tower). This also assumes that wind should travel to the next-closest down-wind outlet. At this point, this is about as far as we can take our intuition without studying this with fluid mechanic simulations or automated wind-tunnel analysis software like Autodesk Vasari. This design project chooses the latter for the purpose of testing and verifying this theory.

Accordingly, the Interior Wind Tunnel Study in Figure 57 shows this condition. It does however go to mention that the importance of trial and error pertains to this study. This wind tunnel analysis was conducted multiple times to try and move air through areas of wind shadows. While this test is useful to generalize possible scenarios, in order to get this more accurate, the indoor occupants may have to adjust these windows manually and on a daily basis. This becomes especially true if occupants want to control unwanted interior wind-speeds, temperatures or directions. Loss of these control measures could lead to occupants feeling warm, cold, and papers flying around the office. Taking notice to the best chosen scenario, Interior Wind Tunnel Study #3 (Figure 57) considers closing windows along areas of the facade as shaded along dashed white lines.

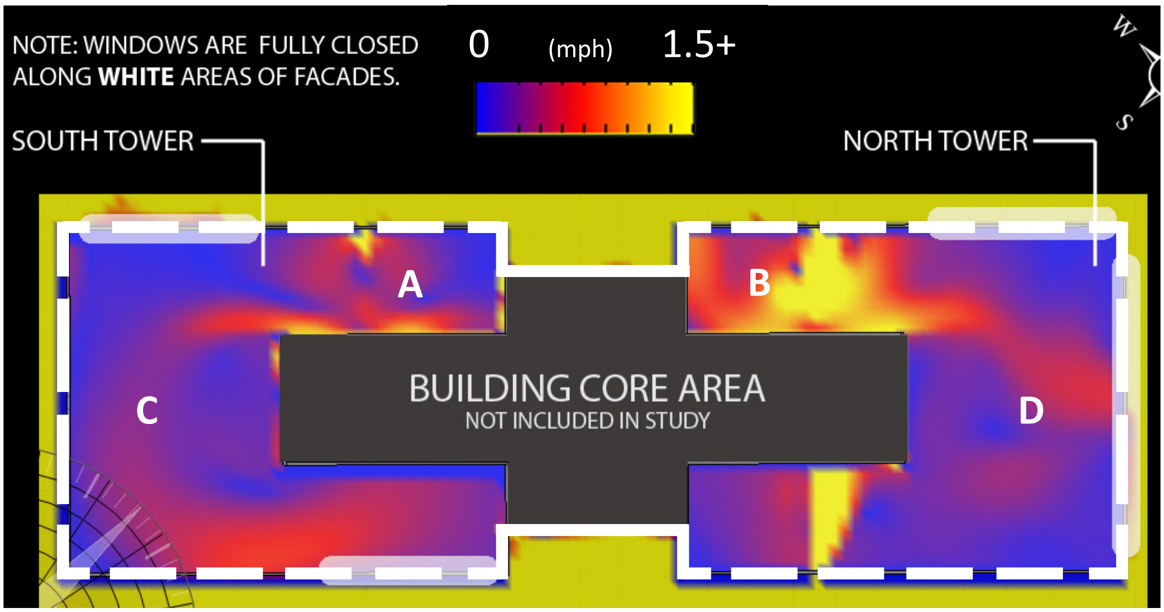

Figure 57: Interior Wind Tunnel Study #3
(Outside ~15mph Prevailing Wind From South)
Source: Autodesk Vasari Beta 2.0, Diagram Generated by Author.

Prevailing Interior Wind Tunnel Study Comparisons Between Figures 55 and 57:

- North Tower windows selectively closed on north and west facades in Figure 57.
- South Tower windows selectively closed on east and north facades in Figure 57.
- More interior air movements occur in previously identified wind-shadow areas, comparing locations "A" and "B" to Interior Wind Tunnel Study #1, Figure 55.
- Average wind speed and circulation is preferred in South Tower area "C" in Figure 57.
- Air movements in North Tower area "D" is further shared with surrounding open office areas in Figure 57.

Now to examine the South Tower further with a 10 mph exterior prevailing wind from south as opposed to 15 mph. For the purposes of Wind Tunnel Study #4 (Figure 58), notice that one additional window has been closed along the southwest facade. This is necessary due to the effect of slower air movements occurring through the office interior. To counter this effect, it is recommended that this additional window be closed to further air movements and allow better circulation for an increased pressure difference on the leeward side. In conducting multiple interior and exterior wind tunnel studies for this building, interior air speeds seem to be within the range of 1/10th of what an exterior prevailing wind is. For example, an exterior wind speed of 10 miles per hour correlates to an approximate maximum of 1mph interior wind speed for this building. Also, interior wind directions are similar to an exterior wind direction. This is of course with the exception to the effects created with the introduction of a wall, obstruction or opening/closing of select windows (as mentioned earlier).

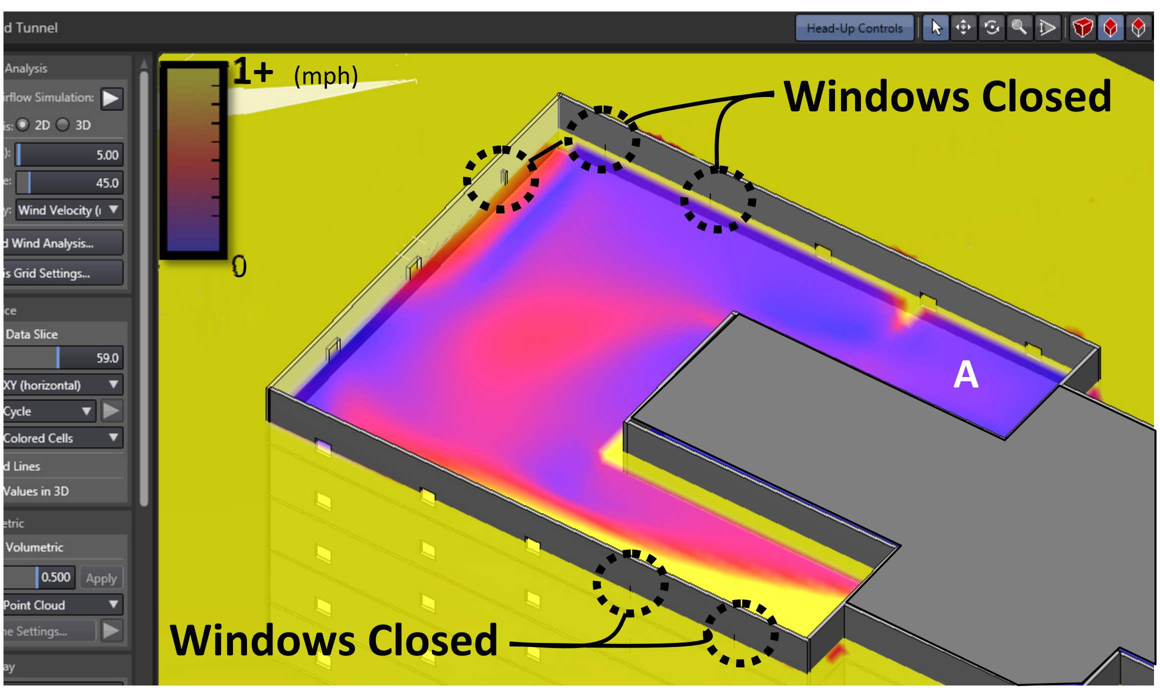

Figure 58: South Tower Interior Wind Tunnel Study #4
(Outside ~10mph Prevailing Wind From South)
Source: Autodesk Vasari Beta 2.0, Diagram Generated by Author.

Proposed Retrofit Design Strategy

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Available Options

There is a delicate balance among sun, wind, light and air temperature to naturally moderate occupant comfort. The first step in analyzing any passive design retrofit strategy for the modern low-rise open office building is to study the existing structure and it's site. After which, one should redraw, with close accuracy, the building facade in section (Figure 59). Special attention should be given to the detail of the curtain wall cavity as this is the primary interface between indoor and outdoor environments.

Note: Dark horizontal lines represent optional interior/exterior shading/ daylighting devices. Dark hatched areas represent areas of new rigid foam behind spandrel glazing. Light grey color represents existing building wall section.

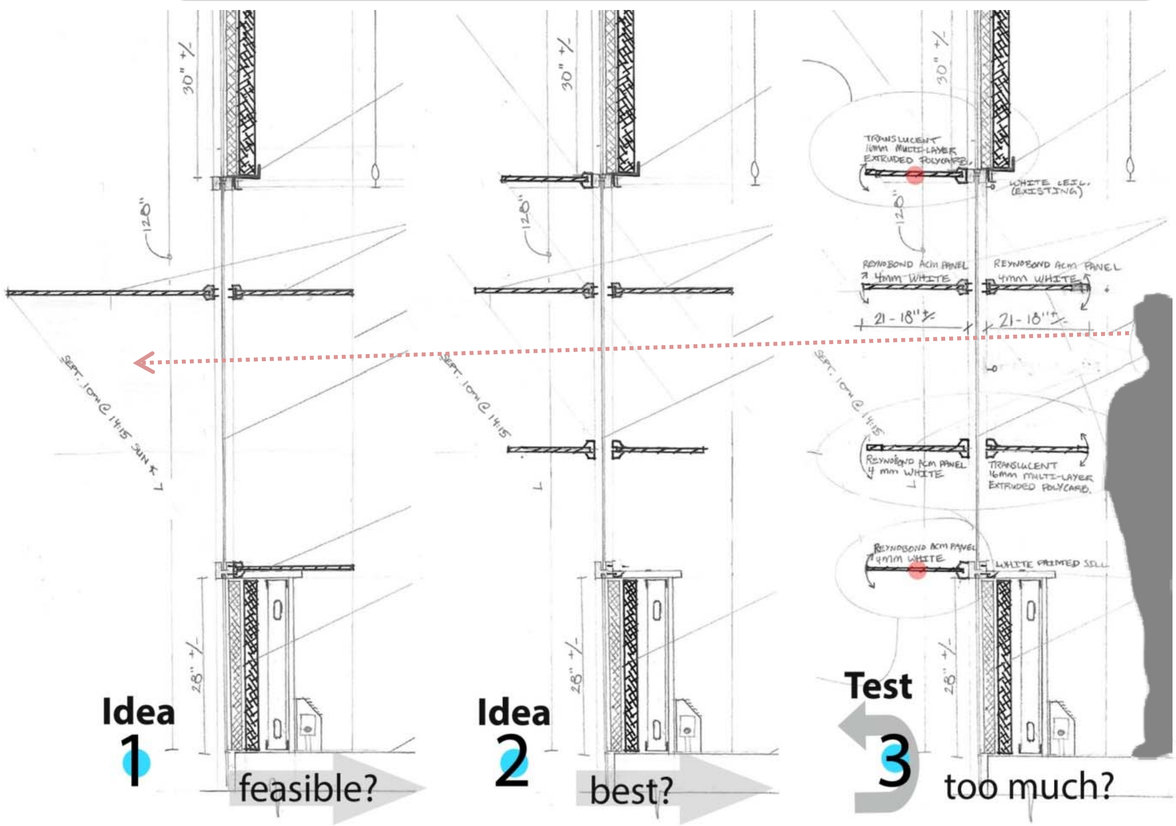

Figure 59: Phasing of Proposed Retrofit Strategy Ideas
Drawing by Author. Note: Existing Facade Shown in Light Grey.

When strategizing a retrofit, the first phase should be to develop an overall strategy. In this case it was to test the theory of removing existing tinted and highly reflective window films to promote the passive strategies of solar radiation and daylighting design as shown in Figure 59. When doing so, shading becomes an issue during warmer periods of the year. Also, since we are in discussion of occupant adaptability within an environment, climate studies become relevant. This is especially true when one takes the passive strategy of natural ventilation into account. For this reason, wind, and thermodynamics should be considered simultaneously with other passive strategies. The best effort now is to triangulate a justifiable solution that caters most effectively to all of these issues.

In retrofit projects, "it is critical to clearly identify what is to be removed, reused, and the amount of protection required for materials, finishes, equipment, fittings, and furniture that will remain" (Gelfand et al. 2012).[131] Accordingly, Figure 59.1 and the following methods shall apply to the proposed retrofit.

Indicates area of new exterior shading and interior daylighting device. Remove existing tinted window film and clean prior to installation of apparatus.

Indicates area of new awning window installation on interior side of building envelope. All other locations shall receive a new fixed pane window. Maintain existing windows as required.

Note: Remove & discard existing ceiling tiles and replace with new high-reflective ceiling tiles within boundary as shown. Provide rigid foam insulation on interior at all spandrel glazing. Remove tinted window films from northerly facing facade and maintain elsewhere unless otherwise noted.

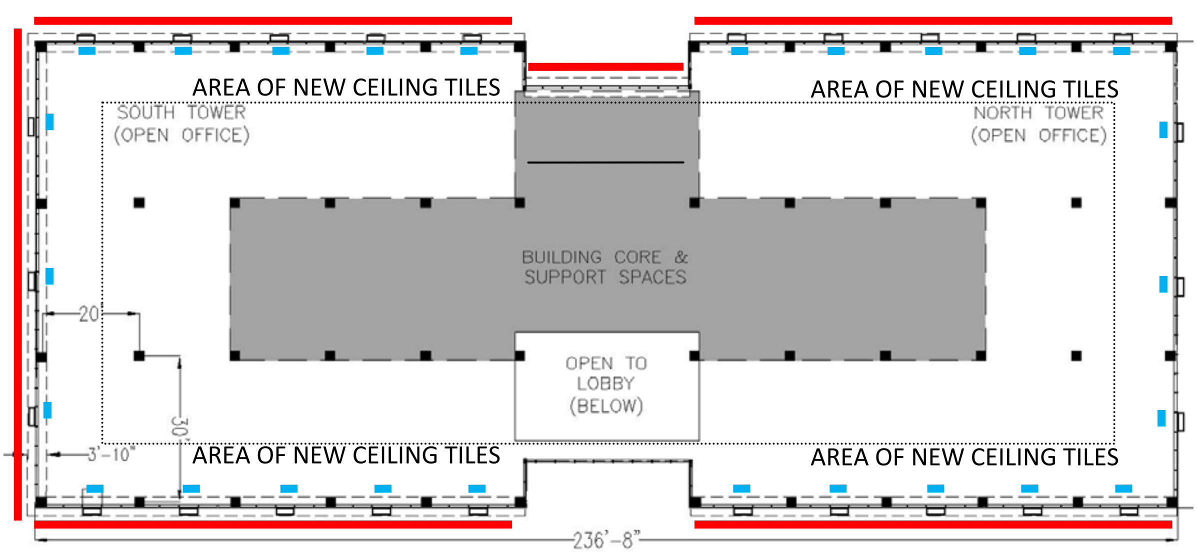

Figure 59.1: The Towers Retrofit Floor Plan
Drawing by Author.

North

[131] Gelfand and Duncan, *Sustainable Renovation Strategies,* 177.

- Remove <u>all</u> existing fixed frame-within-frame (FWF) windows for direct replacement with (3) equal segment quad cavity dual pane heat mirror technology windows (R-value of 20) by Hurd Inc. Match elevation and dimensions of the openings in conjunction with;
- Adding two segments (per window) of upper and lower light/shading shelves by Wausau on the building exterior, in select locations, and;
- Adding two segments (per window) of upper and lower light/shading shelves by Kawneer on the building interior, in select locations.
- Adding 3.5" rigid foam insulation (R-value of 15) behind spandrel glazing at sill walls for each floor, secure with z-clips and silicone as required and;
- Adding 3.5" rigid foam insulation (R-value of 15) behind spandrel glazing above acoustical ceiling tiles for each floor, secure with z-clips and silicone as required.
- Adding Hurd Inc. Ultra-R quad cavity dual pane glazing with heat mirror technology on the interior side of the existing curtain wall facade. Effectively creating a 4-pane/ 6-cavity (combined) existing/new window rated at an approximate R-value of 25.*
- Remove existing reflective tint/film from all windows, on all floors.
- Provide NuHeat heating coil for use through exterior daylighting/shading shelves as required to eliminate icicle formation and snow loads. Connect to existing 120V AC supply at perimeter sills and drill through facade framework as required for connection.
- Add photo-sensors along building perimeter @ 40' O.C. and re-circuit existing 2'x4' CFL recessed light fixtures along building perimeter to include shut-off @ 200 LUX.
- Repaint all interior perimeter walls/column build-outs (including window sill) with White Gloss Paint for reflectivity purposes, all floors, at all windows.
- Replace existing Acoustical Ceiling Tiles along building perimeter and 8' inward with Armstrong White Highly reflective ceiling tiles.
- Provide interior temporary protection and scissor lifts with watchman as required for renovation.

*Assuming adequate waterproofing around original aluminum curtain wall frame edges can be maintained with new window installation. Hurd Ultra-R windows incorporate 3 suspended films between panes, effectively creating four air cavities within the new window section which is approximately 3.5 inches thick and 3.0 lbs/sf (see figure 59.11).[132] This is in addition to the existing double pane insulated clear glass, low-emissivity window and the air space between the two; hence an R value of 25 is assumed.

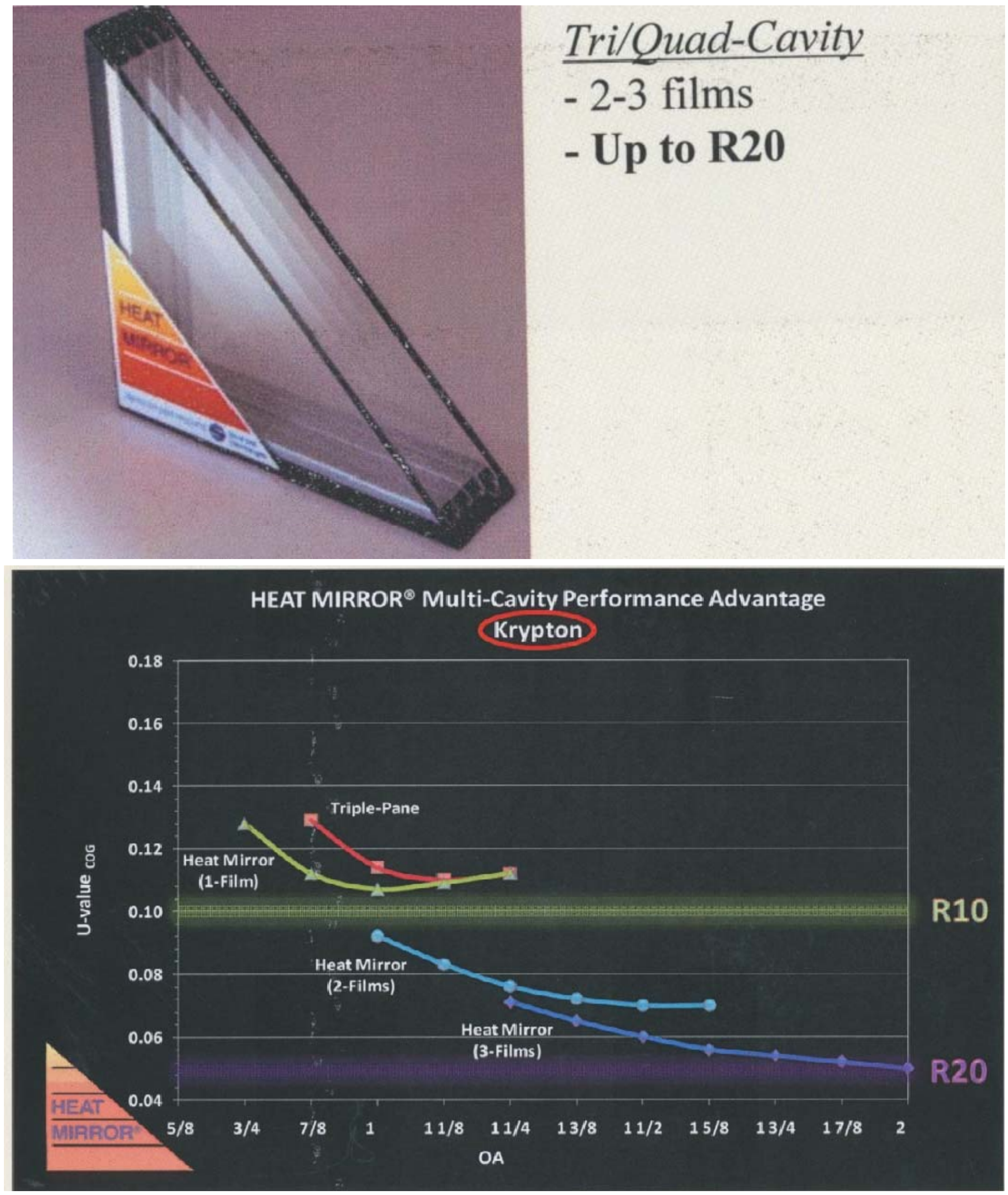

Figure 59.11: Hurd, Inc. Ultra-R Quad-Cavity Glazing Performance
Source: Hurd Inc. Ultra-R Product Manual.

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132 Hurd, Inc. "Introducing the Absolute Best Performing Glass on the Planet," Hurd Windows and Doors, 2013.

Feasibility

For feasibility studies, the next step is to research and identify readily available and cost-effective products that meet the criteria for the passive design retrofit strategy. Apogee Wausau Group Inc., a leading manufacturer of curtain wall systems and building products, has a credible solution to an otherwise complex situation, "a combined shading and daylighting device" (Wausau 2008).[133] This extruded aluminum device (Figure 59.2) installs directly to the exterior of a building's curtain wall system and comes in multiple sizes. Similarly, Kawneer Inc. offers an interior light shelf (Figure 60) known as InLighten and can be screwed to the interior side of a curtain wall system. Both will be used together and considered for the proposed retrofit.

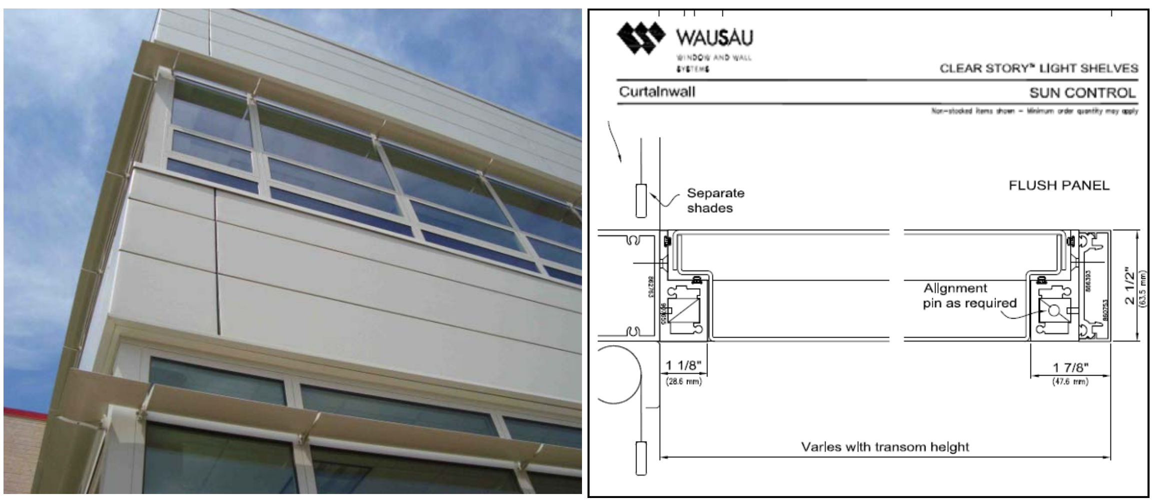

Figure 59.2: Wausau Exterior Shading/ Daylighting Device
Source: Wausau, Inc. 2013.

Both products product appear to be easy to install and are light-weight, having a reflective panel and an extruded anodized aluminum mullion surround. Kawneer's and Wausau's products can be easily utilized to fit this project and are available in varying widths up to 6 feet and varying depths nearing 3.5 feet. They both have a low-profile,

[133] "Architectural Products: Clearstory, Sun Shades & Light Shelves," Apogee Wausau Group, Inc., last modified 2008.

sleek and modern design which makes it on par with the visual aesthetics of a modern office building. Additionally, these shelves have the capacity to be drilled through in the field for on-site installation of the NuHeat heating coil, as shown in Figure 60. Lastly, by pulling the Kawneer unit up and out, it is adjustable to be in a downward/vertical or upward/horizontal state. This allows the interior unit to rotate and minimize glare and makes for easier cleaning. While it may look like a great fit for this retrofit design project, it will need to be tested for its ability to shade and simultaneously reflect daylight and solar radiation. More importantly, it should also be compared to the existing building condition, as this is what a passive retrofit is all about, an improvement over existing non-passive design methods.

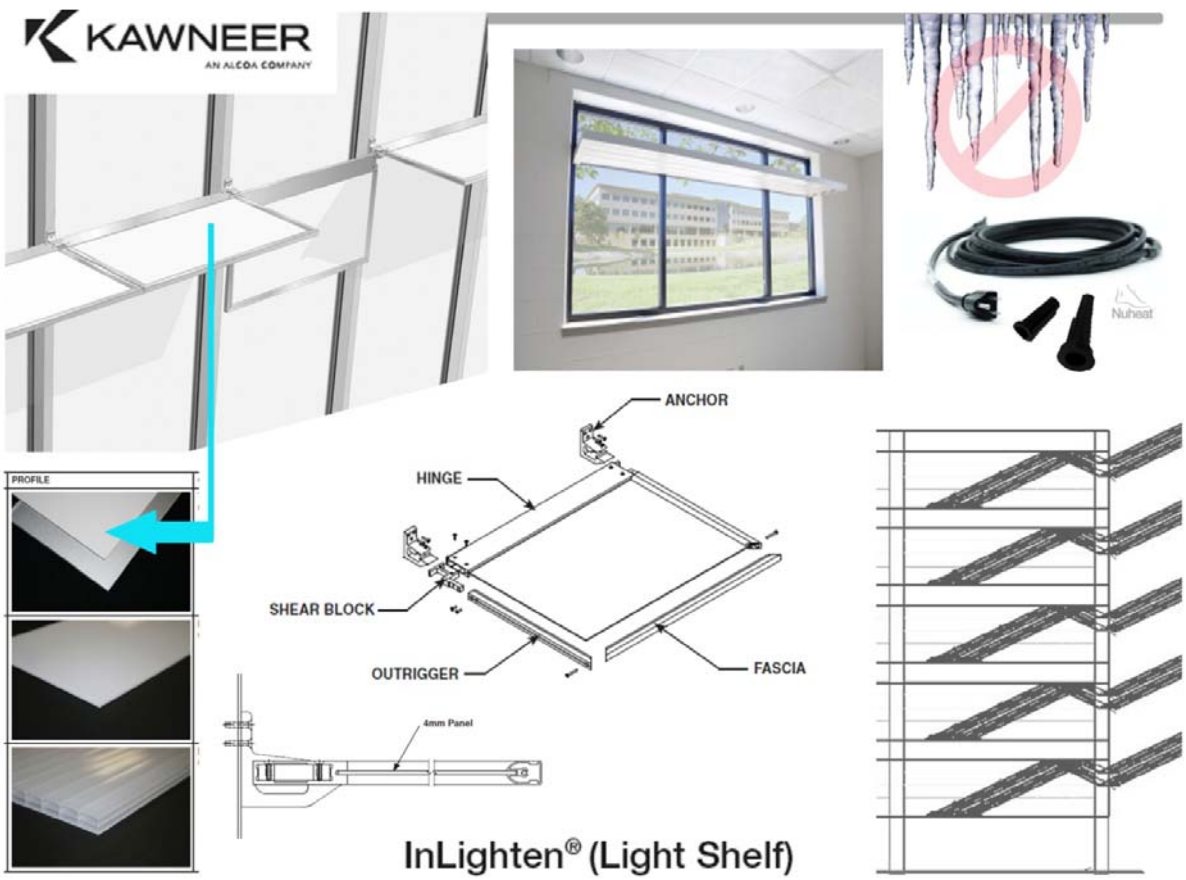

Figure 60: Compilation of Combined Passive Design Strategy
Source: Autodesk Ecotect, Kawneer Inc., NuTone Inc., Diagram by Author.

Application and Methods

The application strategy of the InLighten interior light shelf is very well thought out by Kawneer, Inc. As is the exterior combination light shelf/shading device by Wausau, Inc. For this passive design retrofit, both will be secured to the extruded aluminum mullions of the curtain wall facade on interior and exterior faces. In terms of product profiles, Kawneer, Inc. recommends the 4 mm white fiberglass reinforced composite panel for the highest level of reflectivity. Wausau's product is made of aluminum and has a highly reflective white enamel coating. This retrofit design project will move forward with these specifications and utilize them for daylighting and shading analysis (to follow). Considering this method of application, there will be (4) shelves per window. The dimensions of the interior and exterior shelves shall be specified as 4'-0" width x 1'-9" depth. Exterior load capacities for snow and wind will need to be tested and verified by a structural engineer as additional loads are being introduced to the building envelope. These shelves shall be located at lower and upper levels, so that the window is "split" into three equal parts in vertical dimension. Based on this criteria and the associated surface area it can then be tested for reflection capabilities. As a result, the reflections shown span nearly 25' into the office interior in the most ideal scenario as tested, at 10:00am during the winter. This is due to the low sun elevation which reflects solar rays at an obtuse angle off of exterior and interior daylighting shelves.

Other Factors to Consider

Icicle formation, snow loads, wind-loads, rainwater run-off, maintenance and life cycle analysis considerations will also be important factors to consider. For this retrofit design project, these measures have been taken into account in architectural terms, but may be further elaborated by Wausau Inc., Kawneer Inc. or a structural engineer and/or the contractor performing the work. Accordingly, this design project recommends the use of Wausau's and Kawneer's products as a combined solution to achieve shading and daylighting simultaneously. Figure 61 shows the extension of these horizontal planes on the interior and exterior sides of the study model. It is important to note that the formation of these units has been reduced to a flat plane for shading and daylighting analysis (to follow).

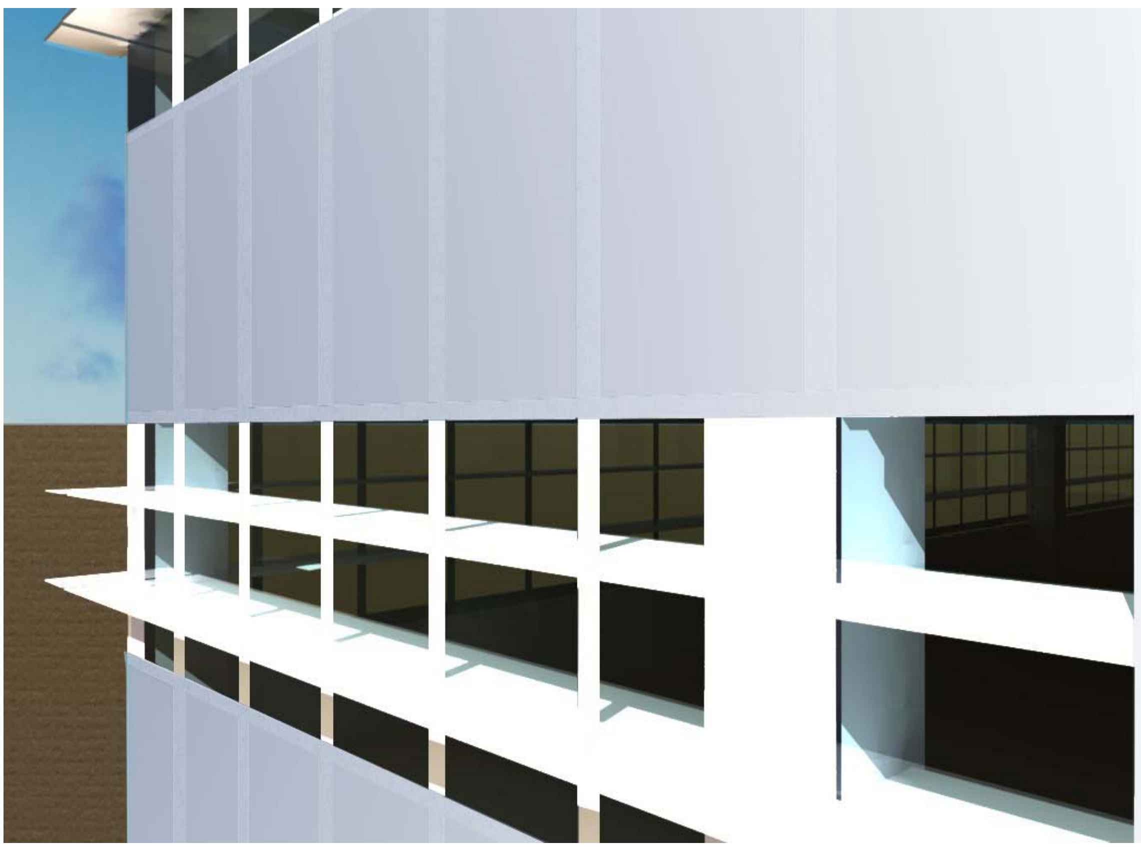

Figure 61: Exterior Retrofit Rendering Showing
White Light Shelves Adjacent to an Aluminum Curtain Wall System
Source: Autodesk Ecotect 2011,
Radiance Photometric Rendering Plug-in, Rendering by Author.

Shading Analysis

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Shading Techniques

Using the specifications of the InLighten Light Shelves by Kawneer and the Wausau exterior shading device, shading strategies can also take place. For one, the building must undergo shading analysis in its current existing state, prior to analyzing the means of improvement and where the retrofit shall occur. Considering this, sun-paths, butterfly shading diagrams and perspective images will help with decision-making.

Figure 62 illustrates the existing building mass and curtain-wall glazing shading factors based on the time of year, sun angle and azimuth. The orientation of the Towers happens to be at a near 45° clockwise angle from north. This creates a tricky scenario that makes Autodesk Ecotect Analysis 2011 a great software to use, rather than manually calculating this added complexity. The Butterfly Shading Diagrams in Figure 62, on January 22nd versus July 22, show this stark difference that is useful for evaluating the proposed retrofit design strategy. Accordingly, winter shadow ranges are wider and occur in more northerly positions. Summer shading occurs in more of an east-west manner and suggests the sun is more overhead during this time. Where areas of shading are darker, more shading takes place and perhaps a different kind of passive design strategy is necessary.

Also relevant to Figure 62 is how the building casts shade upon the site throughout different times of the day and year. Although not included in this study, this may be useful for evaluating heat island affects for paved areas at different times of the day. This could also help a designer consider one landscape design material, over another. In relation to this project, Figure 63 represents the proposed solution for shading and daylighting devices as attached to the building interior and exterior. The illustration is shown in perspective and in section, whereby the red lines indicate a slice of the building at a particular location. Both images in Figure 63 were prepared with Ecotect and will be studied even further.

Sun Paths, Butterfly Shading Diagrams and Perspectives

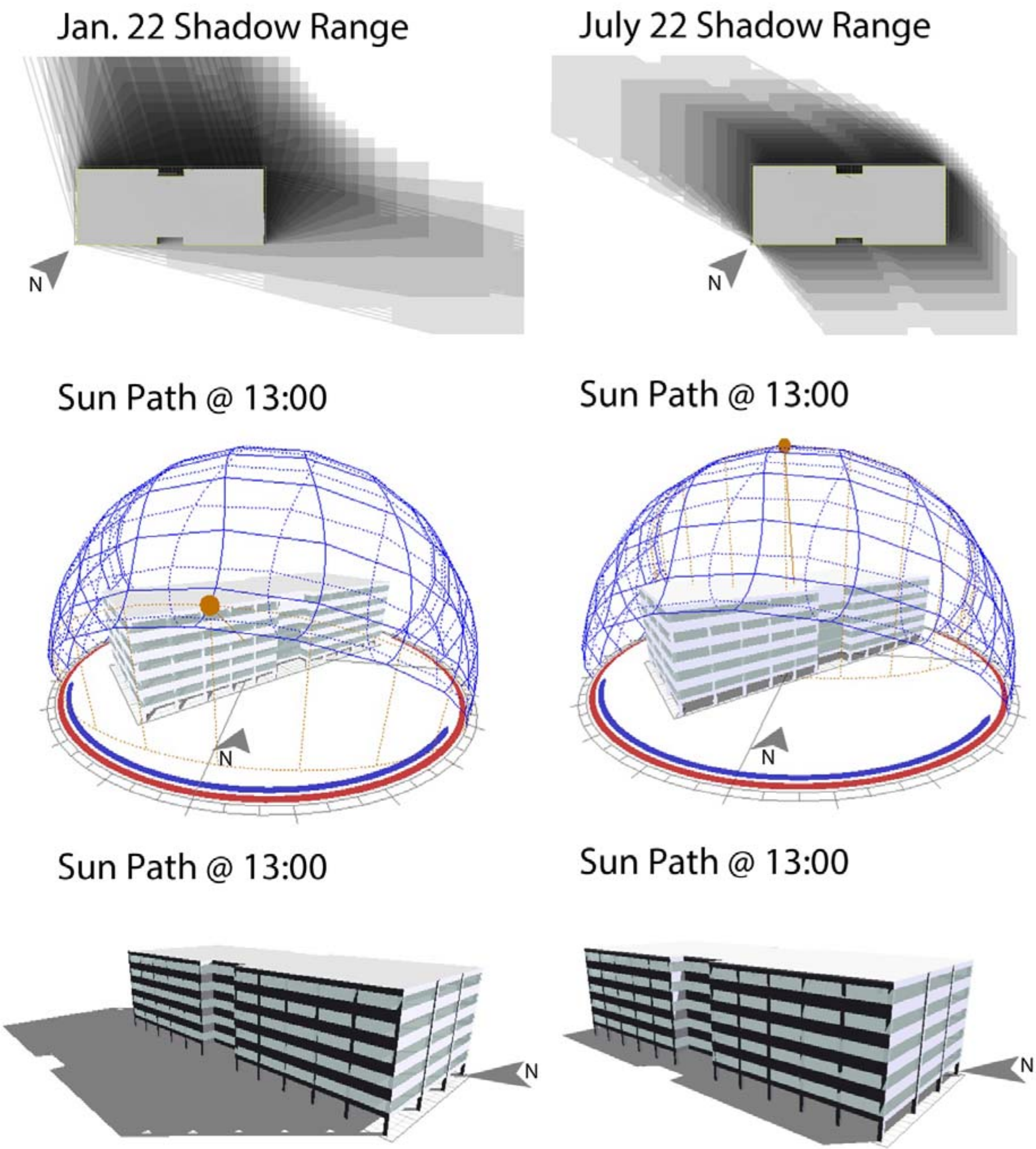

Figure 62: Sun Paths, Butterfly Shading Diagrams and Perspectives on January 22nd and July 22nd at 1:00pm.
Source: Autodesk Ecotect 2011, Illustrations generated by Author.

Application of Retrofit

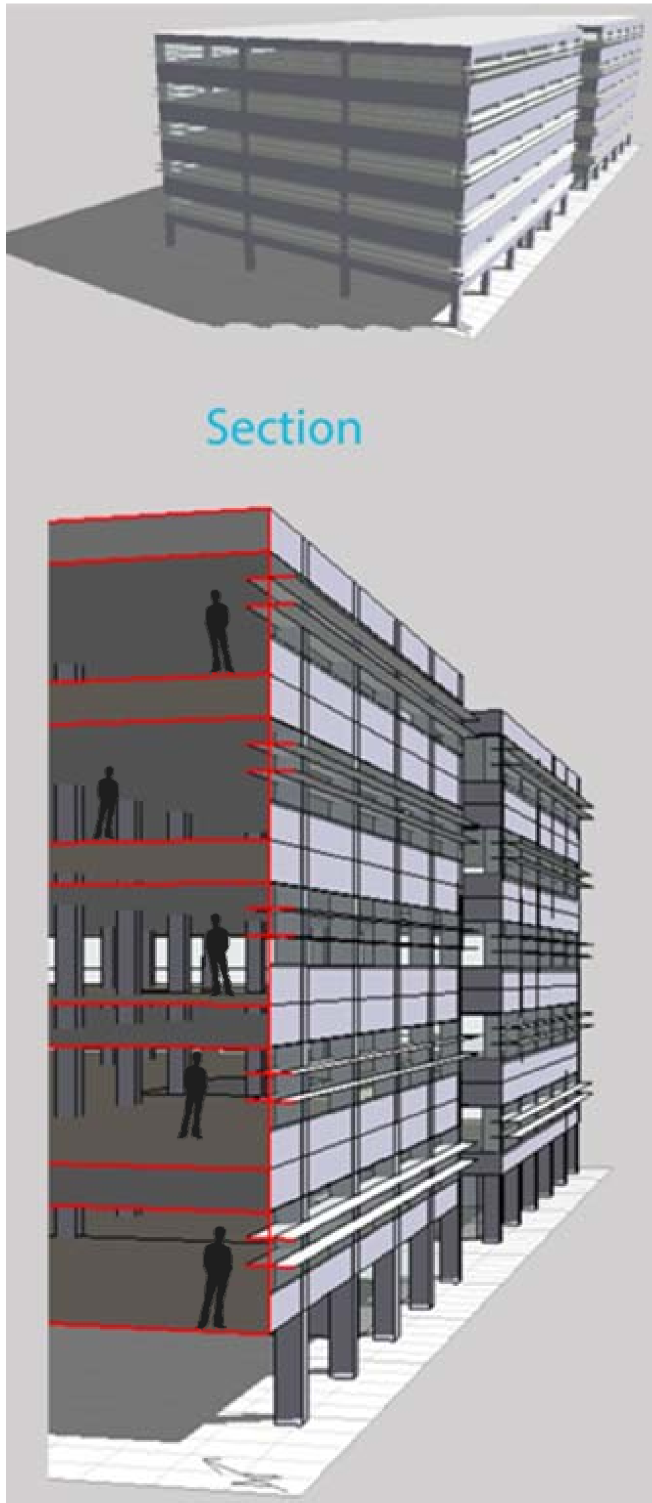

Figure 63: Retrofit Perspective and Section-cut at South Tower
Source: Autodesk Ecotect 2011, Rendering generated by Author.

Daylighting Analysis

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View Angle and Methodology

Based on previous research and specification of the retrofit design strategy, one can now test its effectiveness for daylighting. Using the presiding Viewing Angle for Interior Daylight Comparison shown in Figure 64, one should create a common baseline to compare the proposed retrofit solutions to. For this design project, the camera elevation was chosen at 68" above the finished floor, viewing southeast similar to the photos previously documented. This same location is where all future studies will be tested for direct comparison to eliminate variables in photometric readings at different elevations, view angles and position. The existing building condition with highly reflective/tinted glazing will be rendered without shading or daylighting devices. This daylighting analysis is made possible with the use of a third party photometric rendering plug-in, Radiance 2.0, made available for use with the Autodesk Ecotect 2011 platform.

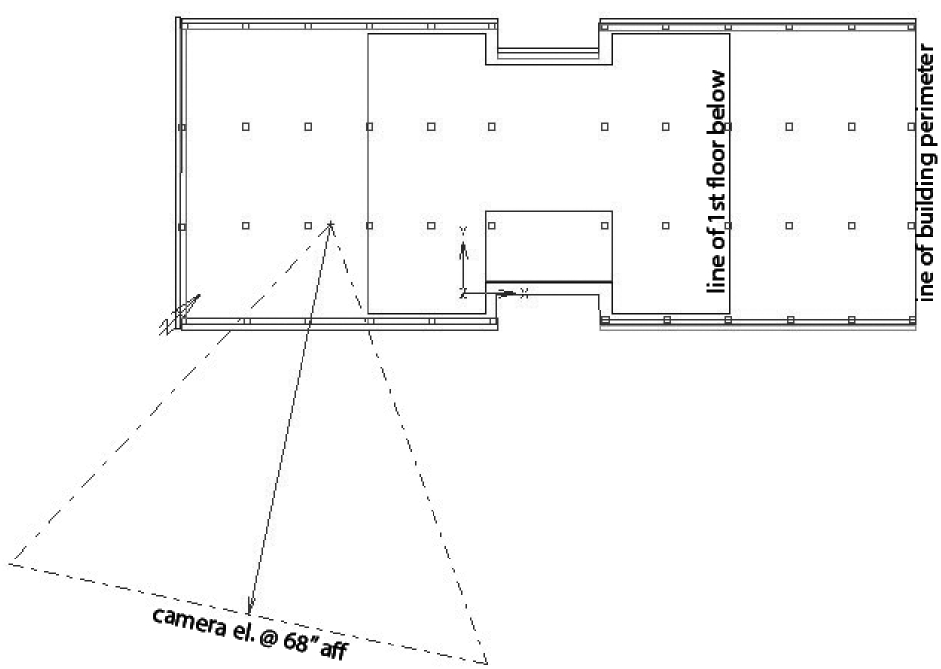

Figure 64: Camera View Angle for Daylighting Studies and Comparisons
Source: Autodesk Ecotect 2011, Illustration generated by Author.

Process and Determination

Since the photometric plug-in is capable of preparing renderings based on illumination intensity and uses Autodesk Ecotect material properties for evaluation, it is a good candidate for environmental analysis. Expediting the process for daylighting evaluation, this software's add-on capability is also an approximation to the real life conditions. Ecotect and Radiance therefore offer the ability to use the sun's path and solar angles, by selecting a date and time, to study daylight levels making them together a perfect candidate for daylighting determination.

After rendering an interior image, one can click upon points within the building model to evaluate Lux levels as shown in Figure 65. Accordingly, this average lux reading illustration captures the existing building's daylighting potential at 11:15am on

Figure 65: Existing Building Interior Daylighting on September 10th at 11:15am
Source: Radiance Photometric Rendering Plug-in, Rendering by Author.

September 10th. Considering general offices should have, at minimum, 200 Lux at a horizontal surface plain 30" above the floor, this illustration depicts the existing daylighting condition falling well short in all aspects where light is reflecting and analysis points are located. In this case, since daylighting is solely considered, artificial lighting is absolutely required, even near the window line. Only at the direct point of where the sun comes through is the level near the required 200 Lux reading. This existing condition is primarily due to the window material properties being highly reflective and dark in tint. Previous research indicates that this type of glazing scenario could reduce daylight transmittance by as much as 88%. Figure 65 makes this understanding seem quite apparent when compared with the proposed retrofit of removing this film. While this may be the case, this film does however block unwanted solar radiation during the summer and without the use of exterior daylighting/shading devices, this may be the next best solution to control glare and heat gain. This is not a justifiable solution though; the effort to design passively and with occupant comfort in mind means we need to allow for more natural lighting, especially if it is readily available. In direct comparison, this daylighting figure will be explored at the same time of day and year. Studies will use previously conducted research as a guide to conduct trial and error experimentations.

To establish a basis for determining the best daylighting solution, a process for evaluation is required. Respectively, Figure 66 shows a direct phasing and comparison of the daylighting retrofit design option with previous research strategies in mind. First, it makes sense to compare the existing condition, "existing/tint", to that of removing the film and leaving the clear glass in an un-shaded state, "clear." Now that we can directly correlate the colors in the image to Lux spot-metrics previously identified, one can move through this process rather quickly and begin to test multiple retrofit strategies for daylighting design.

Having done this, the second phase of testing shows the existing tinted condition with the addition of an upper combined shading/light shelf called "tint/up." We can see little difference with exception to the removal of direct sunlight touching the floor, as this has now become shaded. Comparing this option to the next test; removing tint, while maintaining the same upper shading/daylight shelf, we notice a serious improvement on the amount of daylight being brought into the space. So much so that glare at the upper shelf may be an issue due to the increased surface area and the removal of tinted/reflective window films. Next, by adding vertical fins between curtain wall window frames and adding a lower reflective shelf resting upon the window sill, namely "up/low/fin" we see increased and uncontrolled levels of glare, but do also have an

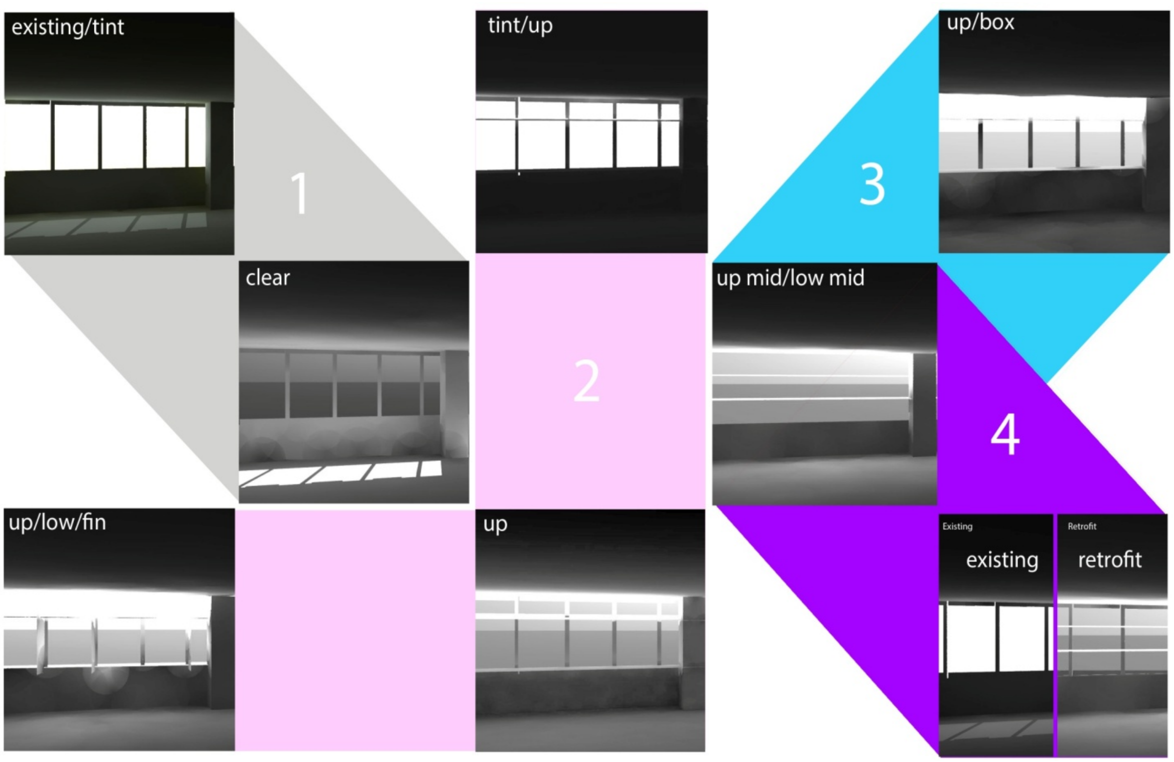

Figure 66: Interior Daylighting and Shading Experimentations to Determine Proposed Retrofit
Source: Radiance Photometric Rendering Plug-in, Rendering by Author.

increased daylight factor based on the amount of brightness.

This being still unacceptable and possibly worse than the phase prior, it is fair to say that reflective vertical fins create more uncontrollable glare from the viewer's perspective. This leads to the next phase (in blue) showing the first step of adding a translucent light-box at the clerestory level. While this is a step in the right direction, the thought comes to mind that *perhaps blocking a view to the sky plane is not such a great idea.* Also, projecting a shading/daylighting shelf nearly 4'-0" from the facade is somewhat impractical and not suitable for the Long Island climate having snowy winters and strong winds. Lastly, the thought of the weight alone, and cantilevering this type of device would be an unnecessary load-bearing burden to the existing curtain-wall mullion structure.

These considerations make feasibility the grounding force, bringing the designer back to reality in search for new ideas. Coincidently, the idea had come to mind to test the use of two smaller depth shelves, leaving equal glass segments above and below on the interior and exterior. This strategy allows for shading to take place without direct sunlight upon floor, while daylighting the ceiling. It additionally provides natural light reflections back to the floor and will bring light further into the space. The softness of light also seemed more spread out in comparison to all previous options. Also, from the viewer's point of view, I was now able to see the sky plane, and considering the thought of approaching the facade, the viewer would also be able to see the ground plane, which is good. These sky and ground plane factors are very important to retain. No wonder why they are a part of zoning and city planning codes throughout the country. Bearing all of these considerations in mind, it was time to compare the best solution for daylighting and combined shading "up mid/low mid" to the baseline condition "existing/tint." The differences are profound and are the primary reason for moving forward to determine the newly improved daylighting levels. Similar to the existing Lux reading illustration discussed earlier, the following daylighting retrofit illustration (Figure 67) is provided.

In summary of the improvements over the existing condition:

•Daylighting Lux levels in similar locations are increased by a factor of two.
•The full color spectrum of light can enter the office space, excluding UV-rays.
•Maximization of diffuse daylight is possible with clear glass and light shelves.
•Office occupants can now view the outdoor environment in its true state.
•Natural light levels reach further into the open office space.
•Energy reductions related to perimeter light fixture off-switching is now possible with the use of photometric sensors.
•Natural daylight levels exceed General Office 200 Lux reading requirement. Office occupants may become more productive and have increased joy.

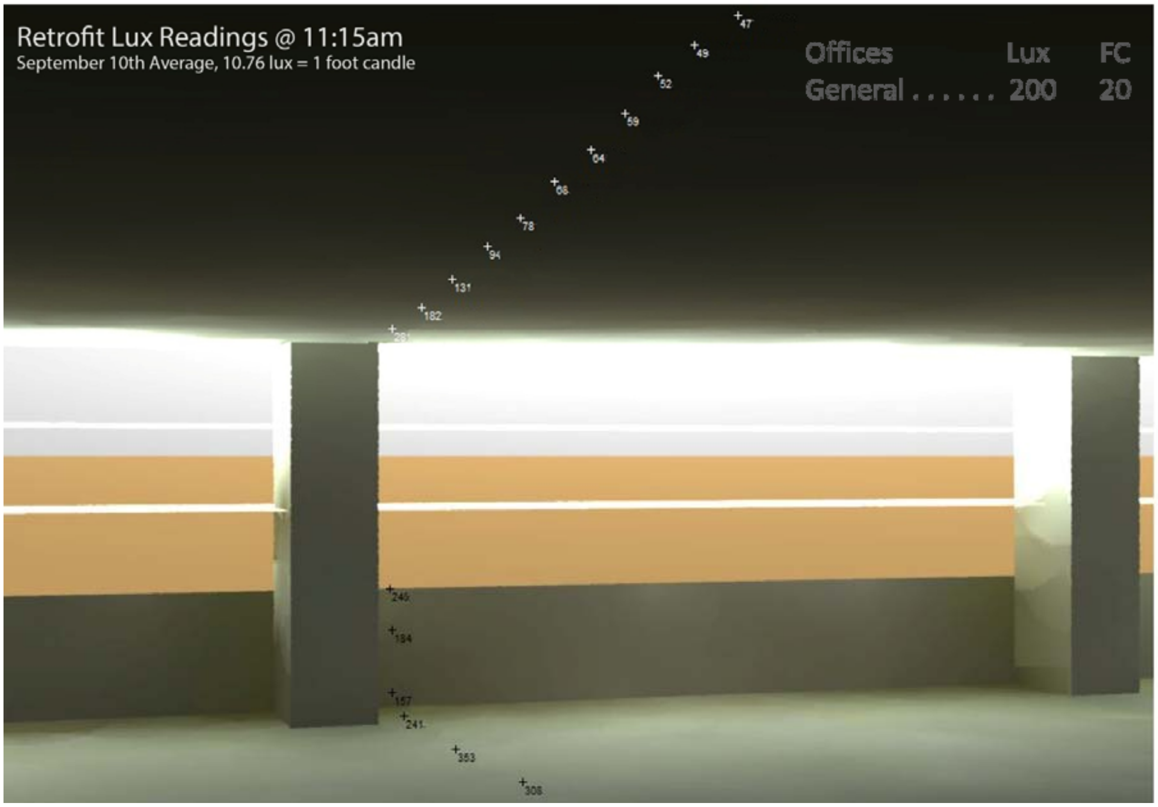

Figure 67: Proposed Retrofit Interior Daylighting on September 10th at 11:15am
Source: Radiance Photometric Rendering Plug-in, Rendering by Author.

Daylighting Comparison

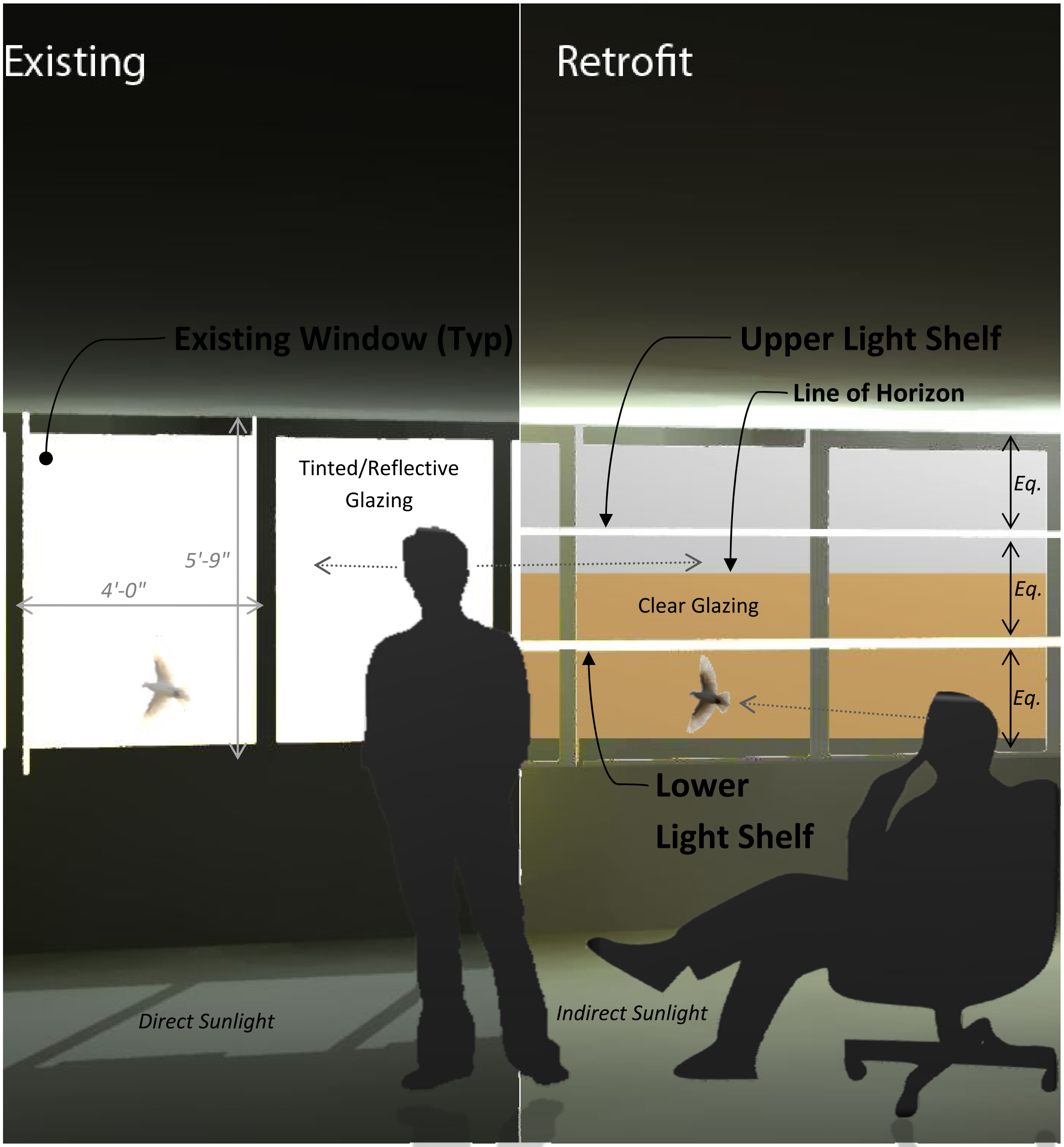

Figure 68: Office Daylight Rendering
Comparison Between Existing Building and Proposed Retrofit
Source: Radiance Photometric Rendering Plug-in, Rendering by Author.

To accompany the retrofit Lux reading shown in Figure 67, Figure 68 shows the daylighting comparison between the existing base building daylighting condition versus the proposed daylighting retrofit. Consideration was given to human line of site in both the seated position as well as the standing position to prove a clear line of sight is unobstructed with the inclusion of upper and lower interior/exterior light shelves. This illustration also gives a clear depiction of how the window is being equally segmented by the retrofit.

Sky Factors

Moving forward, one can further compare daylighting improvements by analyzing sky illumination factors over an analysis grid within Autodesk Ecotect (Figure 69). By manipulating Ecotect settings to show the "Uniform Sky Factor" conditions during the winter, we are using the worst case as a base scenario for evaluation. Data gathering is

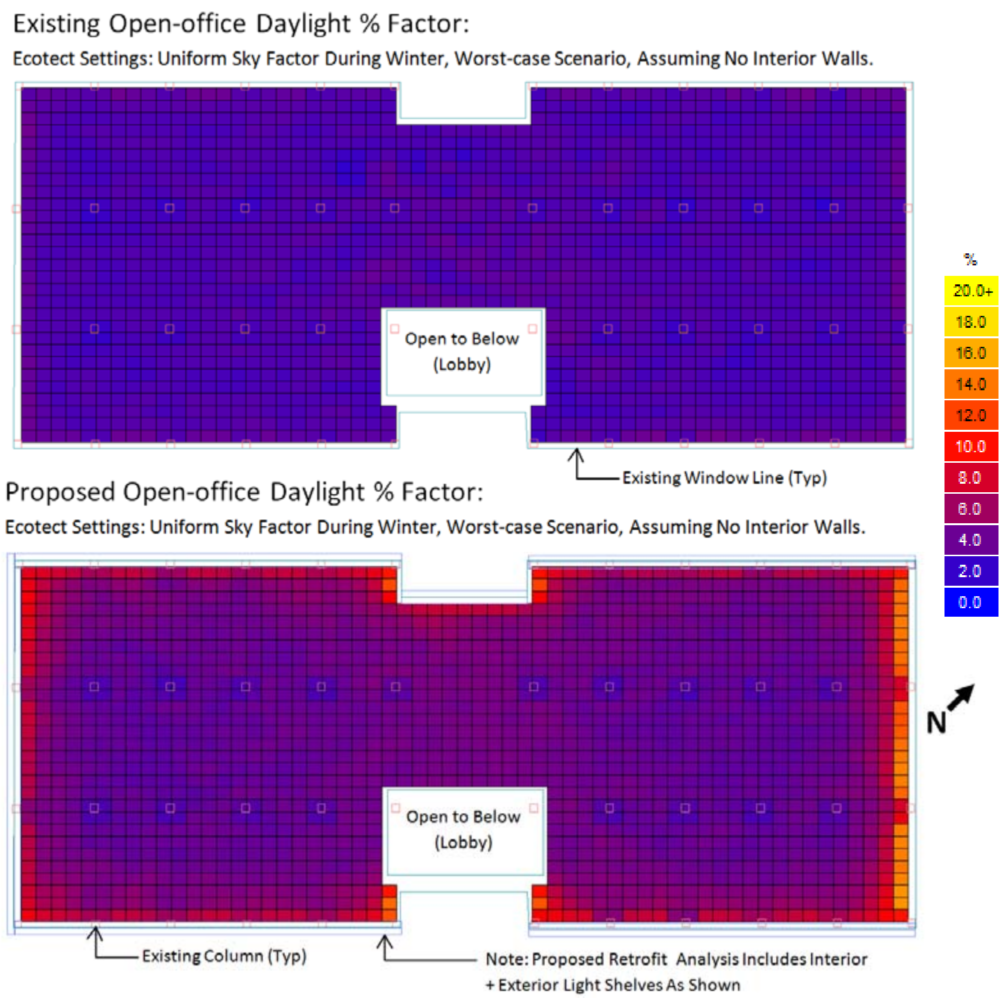

Figure 69: Daylighting Analysis Grid
Comparison Between Existing Building and Proposed Retrofit
Source: Autodesk Ecotect 2011, Illustrations Generated by Author.

conducted over the analysis grid as shown and represents variation by % of daylight factor (100% = full sun exposure).

Overall, Figure 69 shows that the proposed retrofit increases the average daylight factor percentage across the entire open office. When comparing analysis grid squares one can see an average increase in daylight factor percentage, by almost double, over existing conditions. In select instances, especially within the north area of the analysis grid, there is a near 3:1 daylight factor improvement. These upgrades of daylighting are solely due to removing the interior window tint/reflective film from all windows and adding interior/exterior light shelves as previously shown. Where we see the major differences; this is primarily due to increased diffuse daylight that lathers the northern part of the open office, however there are no light shelves here (as there is no form of direct sunlight). Having this in mind, it can be suggested that areas receiving diffuse daylight only, should not have tinted or reflective windows if one is to design a building passively. This criteria can be used as a rule of thumb for any low-rise open office building in the New York Metro area.

Sunrise-Sunset Study

Now that we have a proven daylighting retrofit design strategy in place, one must further ensure we have made the best choice for daylighting design. The last remaining step is to test the retrofit from sunrise to sunset. This will ensure unwanted occurrences are being avoided throughout the workday. Particularly, glare and the inability to control solar radiation are things to avoid. Based upon Figure 70, the sun path is documented from 8:45am to 4:30pm, in 1.25 hour intervals on September 10th. Studies prior to 8:45am and after 4:30pm have been intentionally omitted as there are building structures surrounding all orientations of The Towers. This includes structures that are in the distance as well as those nearby as they will limit direct solar exposure when the sun is at a low angle. This is estimated to occur during early morning hours (before 8:45am) and late afternoon/evening hours (after 4:30pm). Since all near and far structures are elevated above the line of the horizon, this study is somewhat of a realistic estimate for when direct sunlight will penetrate the southeast and northwest facades.

Starting at 8:45am on September 10th, the sun is assumed to have cleared the sky plane angle of nearby structures and will show slices of direct sunlight casting almost 15' from the building facade, into the office interior. At this time there is also ample indirect and diffuse daylight entering into the office farther. This is due to the low sun angle reflection from light shelves and the white ceiling which then reflects to the floor. Notice how the ceiling is day-lit less than the floor inward from the facade; this proves the reflections have been calculated correctly and are not being exaggerated. By 10:00am, nearly all of the direct sunlight is gone and the interior/exterior light-shelves begin to work on reflecting indirect sunlight. At this point, glare is entirely controlled and since September 10th marks the date of when heating needs to take place, a little solar radiation is not an issue. By 11:15am the sun is further overhead without much difference from 10:00am, except that daylighting along the floor and ceiling has began a slight retreat towards the facade. By 12:30pm the sun is near overhead and shows even more daylight retreating back to the facade. This occurs primarily due to the higher sun angle which is now offering more diffuse daylight reflections.

Since clear glass is in place for the retrofit, now is where diffuse daylight will work mostly by itself. The light-shelves become less effective, but the clear glass does make the most of what daylight is available. Between 1:45pm and 3:00pm there is no direct sun angle being reflected, the sun is more overhead and only diffuse daylight is being shown in this view. By 4:15pm the sun has begun to drop back to a low angle. When looking closely, slight daylight is entering at the bottom right of the figure. This is a correct depiction and illustrates the sun entering through the opposite facade at this point. Moving to our last study, at 5:30pm is when most occupants are finishing their workday. The sun does come porously through the opposite envelope and makes its way across to the other side of the building as shown in Figure 70. In gathering all of this information, there are two adjustments needed in early morning and early evening hours that become necessary in order to control glare. Since the *InLighten* light shelves have the ability of being manually rotated to a vertical position, this should not be an issue. It is therefore recommended that the building occupants manipulate their own comfort levels when direct sunlight or glare becomes an issue during these seldom conditions.

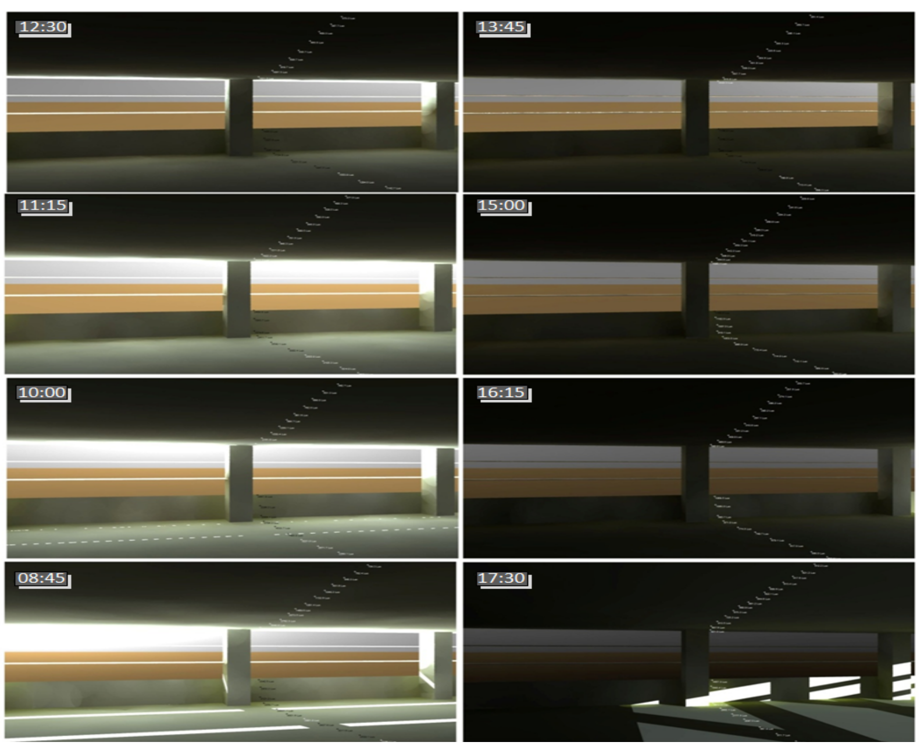

Figure 70: Interior Sunrise to Sunset Daylighting
Analysis for Proposed Retrofit in 1.25 Hour Intervals, Viewing southeast
Source: Autodesk Ecotect 2011, Illustrations Generated by Author.

Solar Radiation Analysis

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Availability

The first step in analyzing solar radiation for developing a passive design retrofit strategy is to see what amount is available to the project site. We are in search of the data that are regionally pertinent to determine when we are able to use direct and/or diffuse solar radiation to our advantage. This is the case when heating becomes a requirement, as opposed to the summer whereby most of the unwanted radiation during this time will be blocked by shading devices. As a reference case scenario, Figure 71 shows hourly solar exposures on December 31st for New York City's latitude/longitude, as contained in the Autodesk Ecotect weather file.

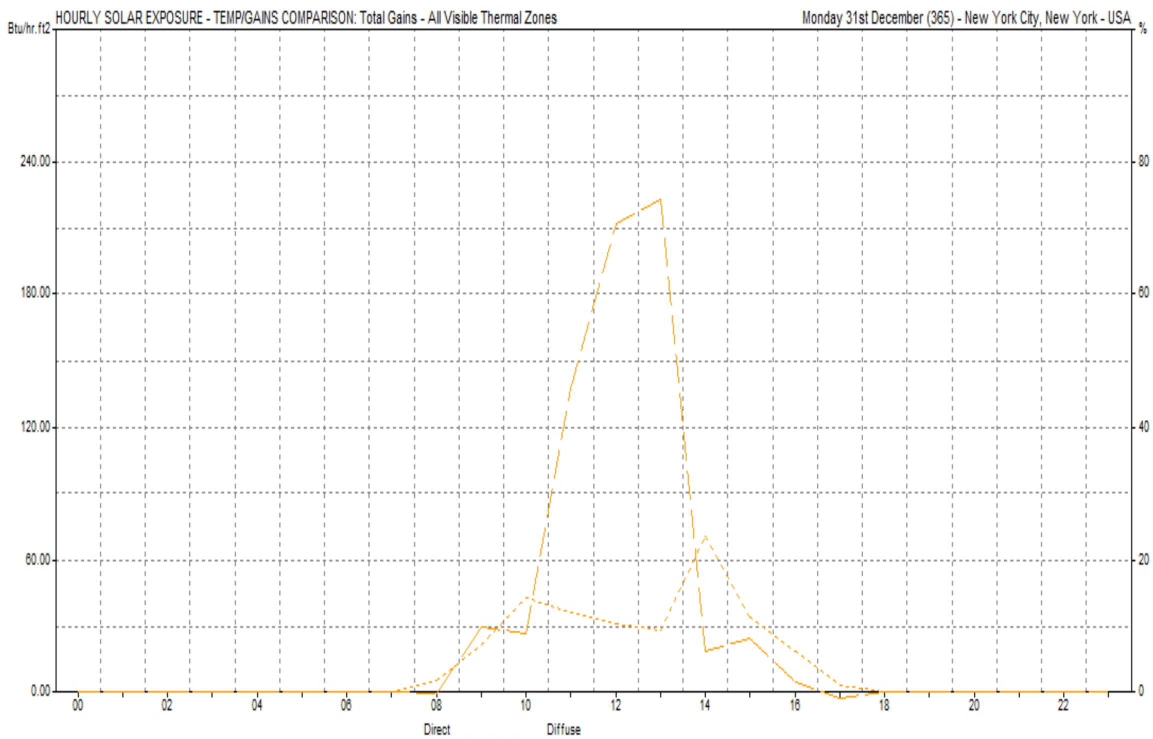

Figure 71: Hourly Solar Exposures and Solar Gain Comparisons
Source: Autodesk Ecotect 2011, Diagram Generated by Author.

According to Figure 71, most of the available solar radiation during the middle of the winter, and particularly on December 31st, occurs from 10:00am through 2:00pm and is direct. This duration and intensity is also consistent with the sun being at a higher elevation, at the highest angle of a day's sun path. Having additional respect to annual solar radiation, the following sun path in plan (Figure 72) best illustrates total direct and diffuse solar radiation intensities throughout the entire year. April-September correlate to the highest Btu/Hr/Sf solar availability, as shown in yellow, nearing 610 Btu/Sf. While the winter is when we need solar radiation the most, these incident values unfortunately prove the opportunity to be somewhat minimal. As noted, there is an approximate maximum of 427 Btu/Sf available during this time and only for a short duration (notice color gradation towards blue). Though this may be true, the important consideration is that we should somehow entertain what is available.

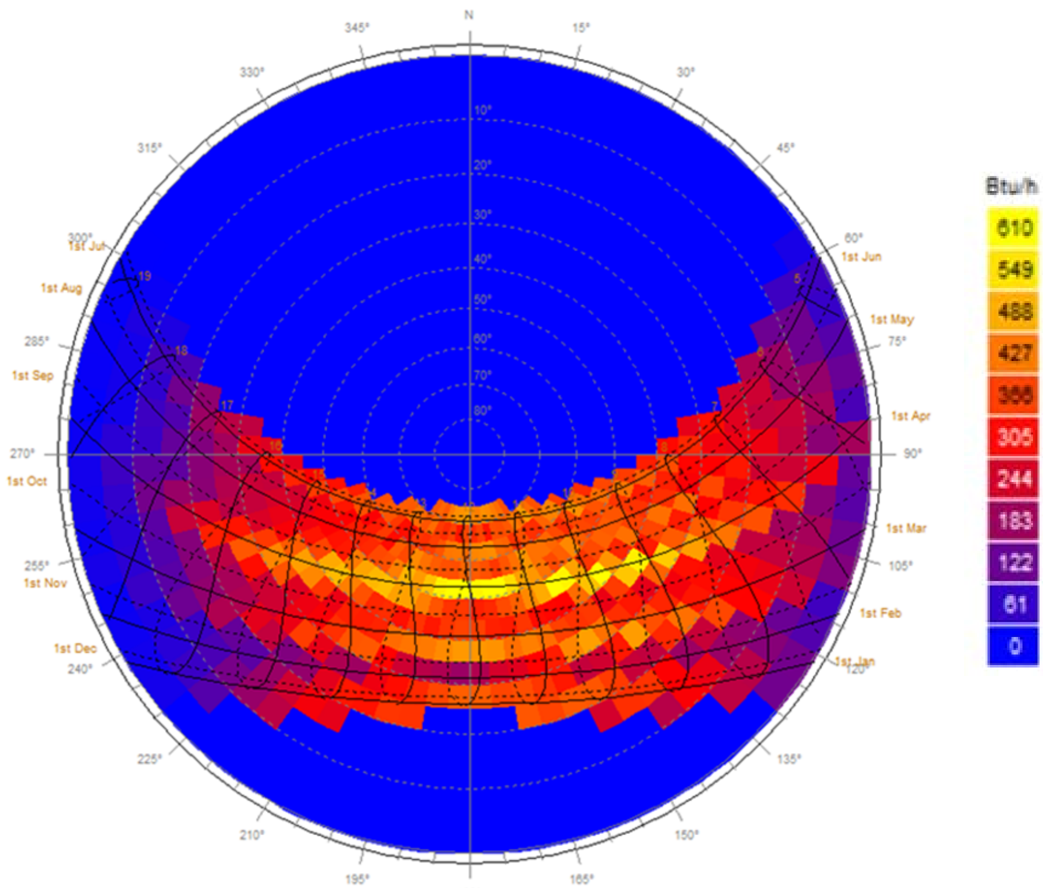

Figure 72: Annual Sun Path Solar Radiation Intensity (Btu/hour) for New York, NY
Source: Autodesk Ecotect 2011, Diagram Generated by Author.

Since the passive design retrofit strategy for shading and daylighting has already been proven and available solar radiation offers minimal intensity when we need it most; it becomes clear that solar radiation should not have the most determining factor for the retrofit typology. However, it should still undergo further analysis to compare the existing building scenario to the proposed retrofit. This makes sure that we know what the desired retrofit will change in terms of direct and diffuse solar radiation gains. We can then see if this loss of opportunity is substantial and whether one should reconsider previous decision making. On this note, Figure 73 provides a better understanding to what happens during the heating season from September 10th- June 6th. These comparative illustrations include incident, overcast and uniform conditions as averaged:

Incident, Overcast, Uniform Conditions and Comparisons[134]

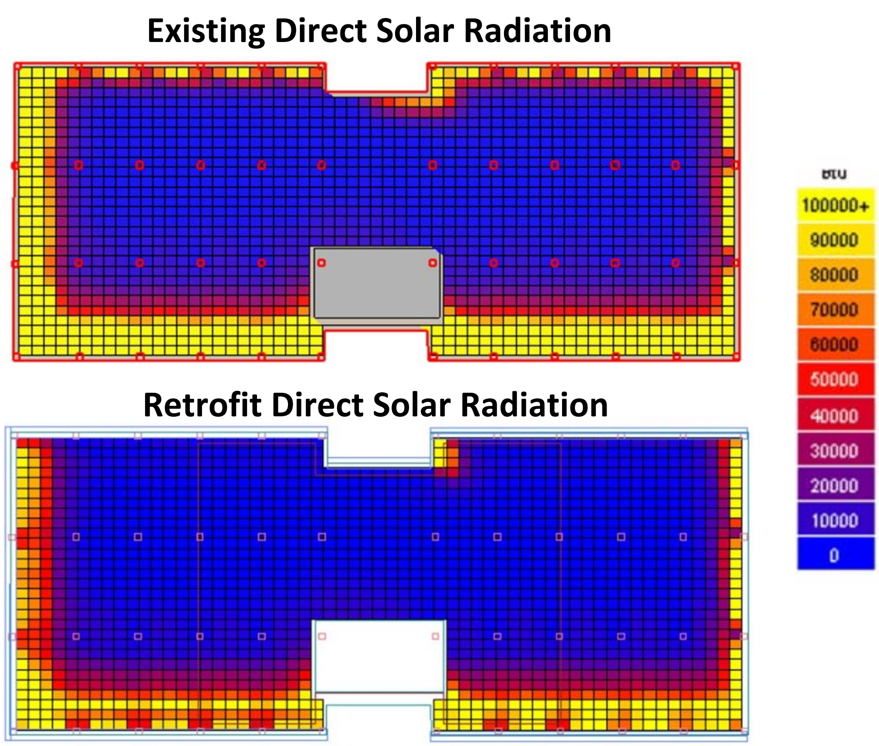

Figure 73: Heating Season Solar Radiation Sky Factor Comparison (Btu) from September 10-June 6th
Sources: Autodesk Ecotect 2011, Illustrations Generated by Author.

[134] "Designing for Thermal Comfort," Ecotect Analysis, Autodesk BIM Curriculum Unit 3, Lesson 2, Tutorial 2, July 9th, 2011, Web, www.youtube.com/watch?v=JxsOPbjjiHs.

The "Existing Direct Solar Radiation" amounts are apparently higher than the proposed "Retrofit Direct Solar Radiation." This increase is evident along facades receiving direct solar exposure and for the retrofit, where daylighting/shading devices are located. An equal amount of solar gain seems to be occurring on the north façade for both instances. This is primarily occurring near this facade as shading/light shelves are not blocking the available solar radiation. The protruding shelves cast a shadow upon the building, they also substantially minimize available solar radiation. This can only mean one thing; incident solar radiation is being absorbed and/or reflected by the daylighting/shading devices. To make sure this is the case, a study comparing externally reflected solar radiation levels is useful. Figure 74 shows this direct comparison.

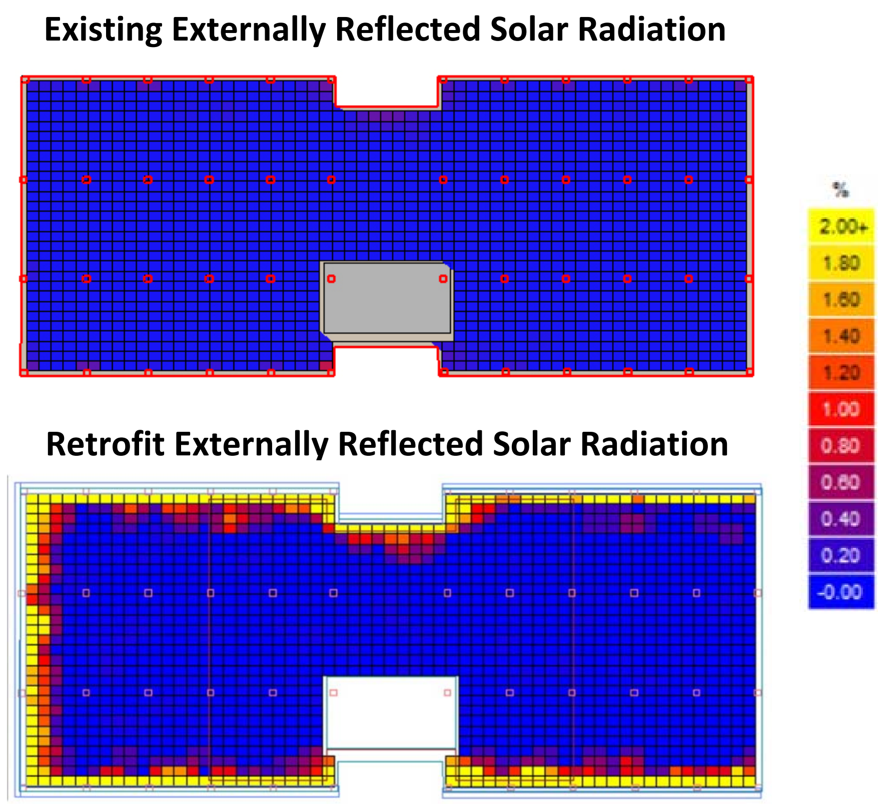

Figure 74: Heating Season Solar Radiation
Sky Factor (%) Comparison (Btu) from September 10-June 6th
Sources: Autodesk Ecotect 2011, Illustrations Generated by Author.

This stark comparison indicates while there is solar radiation being reflected, these values happen to be minimal (2.0%) compared to what is available (100%). Overall, we can say that the shading and daylighting devices will minimize Total Solar Radiation throughout the year. Accordingly, the next two perspective images in Figure 75 show the primary difference in “Total Radiation” for better understanding.

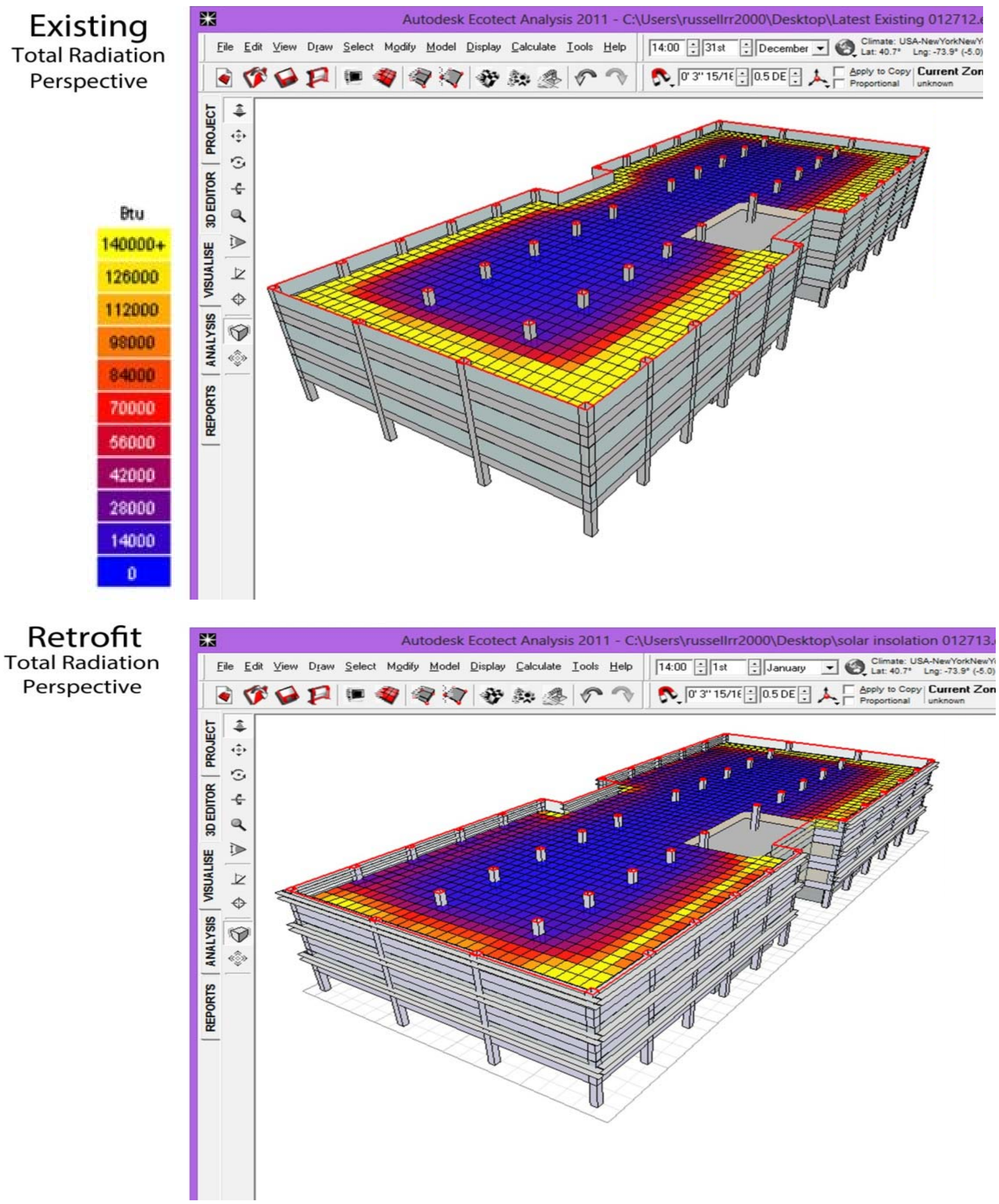

Figure 75: Annual Total Solar Radiation
Existing Building and Proposed Retrofit Comparison
Sources: Autodesk Ecotect 2011, Illustrations Generated by Author.

This is where a tradeoff needs to take place; slightly less solar radiation during the winter and considerably more shading and daylighting during the rest of the year. One should make the decision for the stronger of the two, which is in favor of other passive design strategies. Fortunately enough this seems like an easy choice. Clear glazing allows for ample daylighting and can be well protected during the summer (shading devices). It also allows for better occupant views and helps to "remove the barrier" between indoor and outdoor space. While the importance of having natural light enter a workspace is not completely measurable, it can however be argued that increased daylighting offers human/ psychological advantages. According to Frank Mahnke (1996), "humans may be considered as having total color vision which means that the total spectrum is necessary for our survival and psychology."[135] It also well known that this concept allows the building to conserve energy related to perimeter office lighting fixture off-switching. This is considered on the basis that photo sensors and re-circuiting of light fixtures are required. Estimated energy savings calculations related to off-switching will be described later.

Thermal Imaging

As a supplementary study to this design project, a FLIR Inc. thermal imaging device has been used to study the existing building envelope. The idea behind this analysis was to develop relevant concepts regarding the subject of thermodynamics in a hands-on manner. It will also provide an increased ability to determine areas of heat loss and gain. Lastly, this type of analysis can unveil the differences of solar radiation's affect upon a material’s conductivity. Using this subject, the thermal imaging device establishes spot-temperature readings whereby material comparisons can be made. Particularly, this

[135] Frank Mahnke, *Color, Environment & Human Response*, (New York: Wiley, 1996), 12.

analysis has been conducted with aluminum and glass types in the shade versus direct sunlight.

Figure 76 illustrates FLIR interior thermal imaging scanner temperatures as taken from The Towers Lobby, viewing southeast on January 5th, 2013 at 1:00pm. By this time of the day, the sun is near maximum elevation and at its strongest level. When comparing the thermal imaging photos, attention should be given to where the thermal imaging cross-hair is as well as the temperature variation is indicated at the bottom of each screen-shot. This series of images informs spot-temperatures at each cross-hair and is based on what material is being evaluated.

Starting from the utmost image at 68.4° F reading, we see the interior side of the existing building curtain wall glazing analyzed under complete shade. Moving left and downward the series of images in Figure 76 shows an increased spot-temperature as materials receive more direct sunlight. When comparing the same type of glazing in full shade versus full sun we find a temperature difference of 21.6° F. This is also indicated by the intensity of colors; orange and yellow having the higher spot-temperature values. Also, we notice that as the thermal imaging camera screen-shots near aluminum window mullions, glass temperatures start to increase. Comparably, the difference between glazings in complete shade, versus aluminum mullions in direct sunlight can be as much as 27.6° F.

When looking at a corner condition that appears to be receiving direct and reflected solar radiation, possibly for longer periods of the day, we see the spot temperature is very hot (103° F). the important things to remember is that these glass and aluminum materials are along the same facade, yet we notice these stark differences. The conclusion we can draw from this is that aluminum is a far better absorber of solar radiation than is the tinted and reflective glazing. Now to compare clear glass, versus tinted/reflective glass along the same orientation, the screen-shots at the bottom-left show that clear glass will limit the amount of incident solar radiation upon the building envelope. This can only be the case if one more condition is true; since solar radiation is available, and incident levels are not as high for clear glass, it must be entering the space and occurring elsewhere. This is a good thing, as these measurements have been taken with respect to the heating season. This means that clear glass, when compared to tinted glass along the same exposure, has the ability to allow more solar radiation to enter the space during the winter. This can also be represented by the following Autodesk Ecotect Average Hourly Planar Radiation illustrations in Figure 77 for September 10th-June 6th.

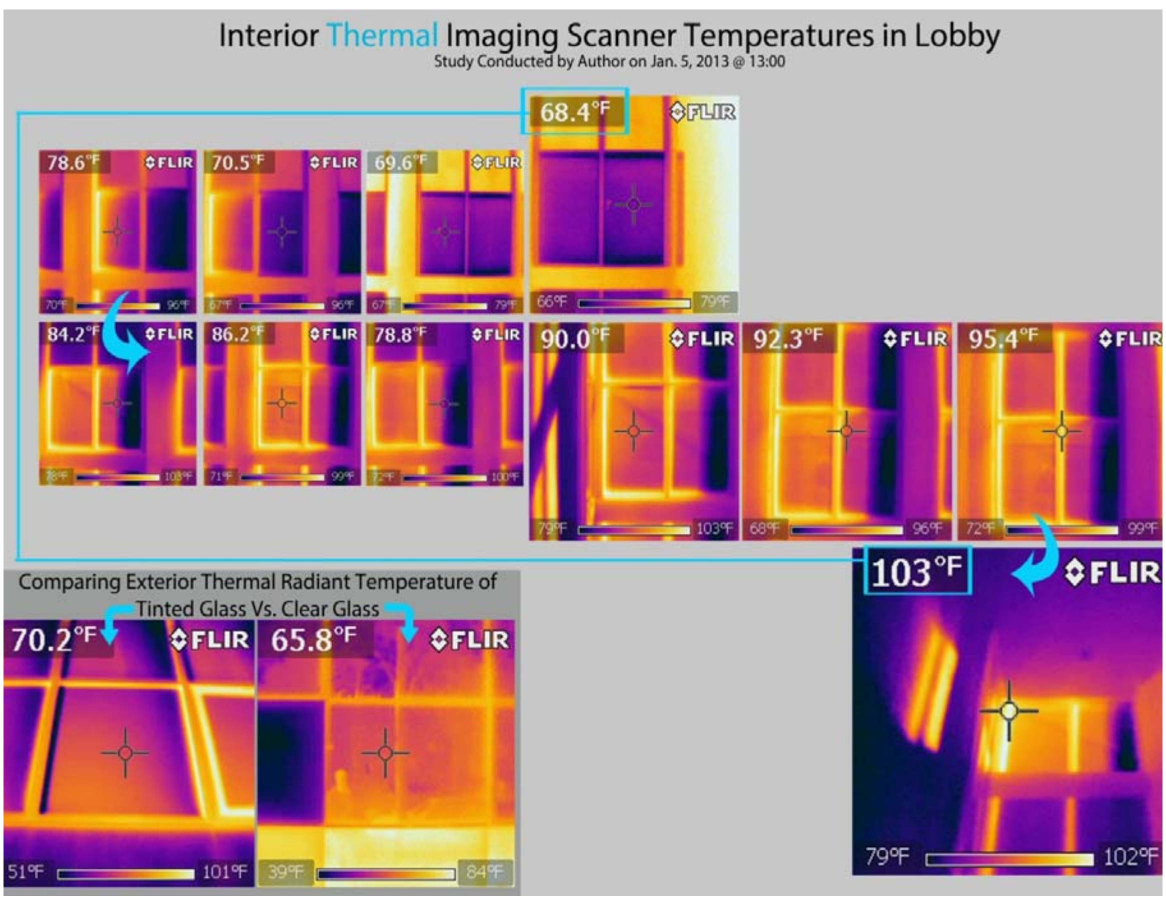

Figure 76: Spot Temperature Study with FLIR, Inc. Thermal Imaging Camera
Study and Illustration by Author.

When comparing Thermal Imaging Camera results to Ecotect's solar access analysis diagram, we can further substantiate this difference by a 20% increase in Watts Per Square Meter (W/m^2).

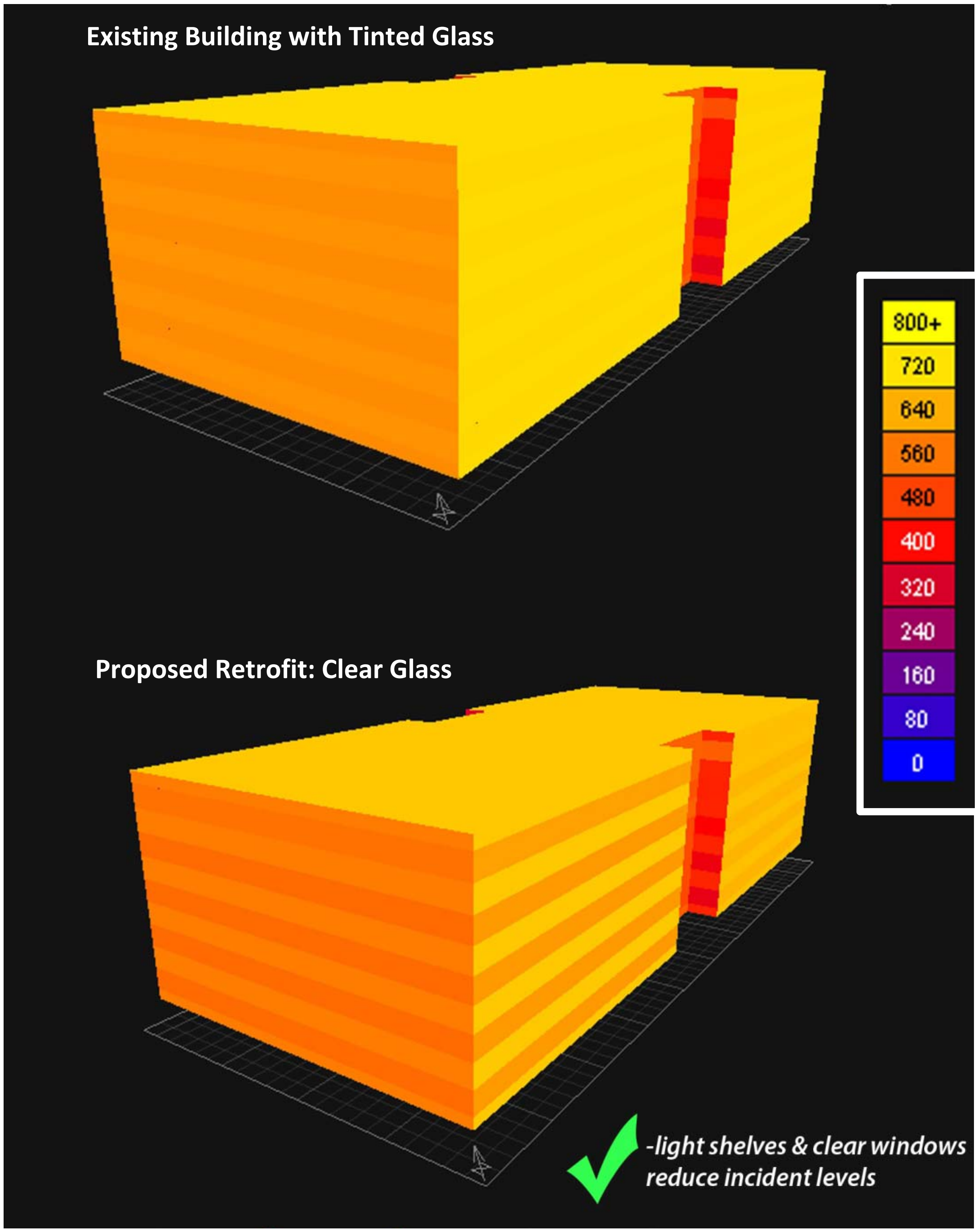

Figure 77: Average Hourly Planar Solar Radiation (W/m^2) for September 10-June 6th
Sources: Autodesk Ecotect 2011, Illustrations Generated by Author.

The best passive design solar radiation retrofit strategy (for this type of building, in this region) is one that will allow increased solar radiation for heating seasons and minimized levels for cooling seasons. One response that comes to mind is to remove the proposed daylight/shading shelves from the building exterior (as the proposed device allows) and provide more conductive materials as the interior shelf surfaces. This strategy creates a task for building maintenance personnel to manipulate, but will improve the building envelope's ability to disperse natural warmth to the office interior while allowing daylighting and having some control over glare in the winter. This must be done in a controlled and comfortable manner though, as there are current measures in place for managing views, glare and daylight, amongst thermal exchanges.

Another solution could be to cover the interior side of the lower window segment (flipping down the lower interior light shelf) with a perforated metal panel at its underside. Heating seasons should not use natural ventilation, therefore non-operability of windows will not be a drawback to this option. Like other passive strategies determined at this stage there is a tradeoff, increased heat gain during the winter and less occupant views during the winter. The last strategy that comes to mind is to replace the interior light shelves with increased depth shelves. While this is possible, and is more desired for controlling glare, it becomes impractical as it further protrudes into the interior office areas from the facade. This concept creates walk-ability and wheel-chair hazards and does not meet the Americans with

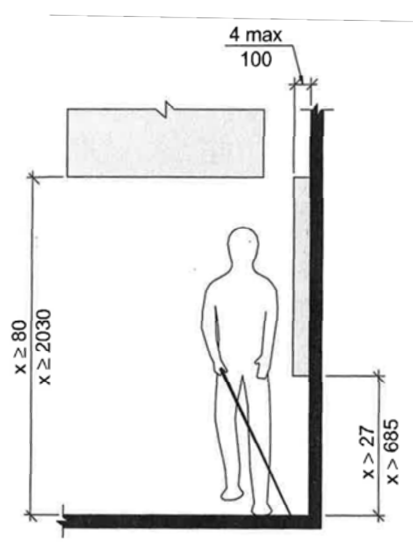

Figure 78: Maximum Interior Projection from Wall
Source: International Building Code

Disabilities Act Code (Figure 78). The code that becomes relevant is the maximum obstruction dimension below 6'-8". Accordingly, 4" is the maximum projection below this elevation and constrains the designer from choosing a deeper interior daylighting shelf according to Figure 78, with measurements in inches.

In the case of this passive design retrofit project, the most ideal scenario that considers cost factors includes:

•Uses conductive aluminum panels on interior light shelves (attach/remove by Velcro) and if possible, remove them from June 6th-September 10th, and
•If possible take away external shading/daylighting devices during the heating season.

If these passive solar manipulations become difficult for maintenance staff to handle, it is advised that the exterior shading/light shelves remain as previously designed for daylighting and shading as there will be no major passive design failure here. Rather, the subtle opportunity of accepting more winter solar heat gain will be lost.

Thermal Comfort Analysis

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Occupant Profiles

Figure 79 represents occupant profiles throughout the workday. It has been assumed that at 6:00am occupants begin to enter the office space and by 9:30am, the building is fully occupied. Starting again from 10:30am, the occupant load will reduce by 50% at 12:30pm as this is during lunch hours. From 12:30pm to 2:30pm occupants are assumed to come back to the office whereby the building is again fully occupied. Starting from 4:00pm, people are assumed to start leaving the office and by 6:00pm there is less than 10% of building occupants remaining. This hourly operational profile shall be used for space heating and cooling load studies and will affect internal heat gains from occupants. These assumptions make for a closer determination to an actual office workday scenario.

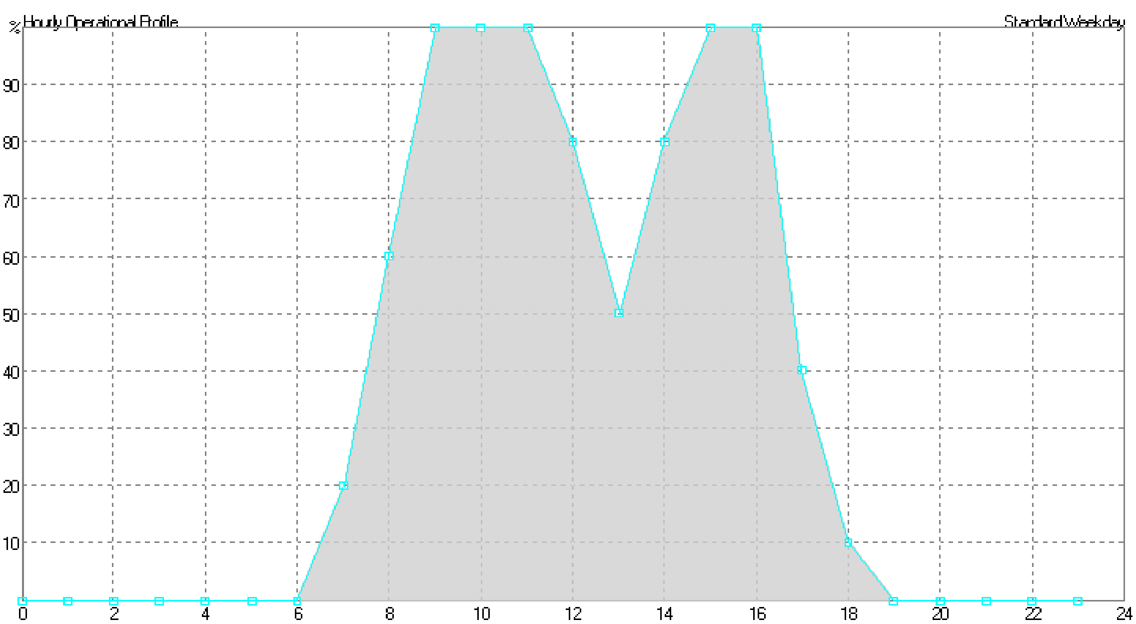
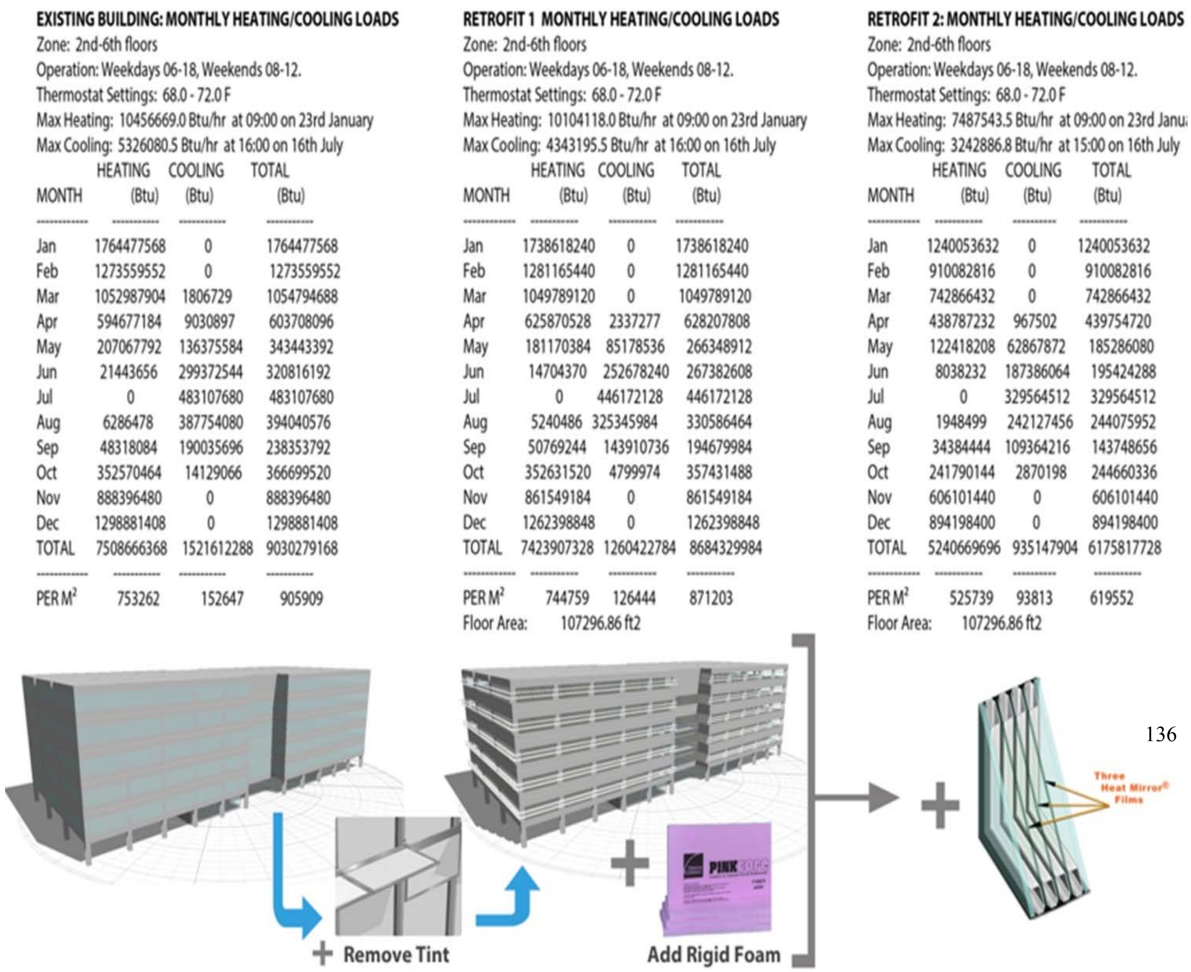


Figure 79: Hourly Operational Profile for an Office
Source: Autodesk Ecotect 2011, Illustration Generated by Author.

Space Loads

Based on the hourly operational profile in Figure 79, space heating and cooling loads can be determined for the existing building and the proposed retrofits. Accordingly, Figure 80 shows the adjusted monthly heating and cooling load values as determined by Ecotect in British thermal units (Btu). The existing building is the "as-is" scenario, assuming no modifications are made. Retrofit #1 captures the changes from removing existing tinted/reflective films from glazing to adding shading and daylighting devices as



EXISTING BUILDING: MONTHLY HEATING/COOLING LOADS
Zone: 2nd-6th floors
Operation: Weekdays 06-18, Weekends 08-12.
Thermostat Settings: 68.0 - 72.0 F
Max Heating: 10456669.0 Btu/hr at 09:00 on 23rd January
Max Cooling: 5326080.5 Btu/hr at 16:00 on 16th July

MONTH	HEATING (Btu)	COOLING (Btu)	TOTAL (Btu)
Jan	1764477568	0	1764477568
Feb	1273559552	0	1273559552
Mar	1052987904	1806729	1054794688
Apr	594677184	9030897	603708096
May	207067792	136375584	343443392
Jun	21443656	299372544	320816192
Jul	0	483107680	483107680
Aug	6286478	387754080	394040576
Sep	48318084	190035696	238353792
Oct	352570464	14129066	366699520
Nov	888396480	0	888396480
Dec	1298881408	0	1298881408
TOTAL	7508666368	1521612288	9030279168
PER M^2	753262	152647	905909

RETROFIT 1 MONTHLY HEATING/COOLING LOADS
Zone: 2nd-6th floors
Operation: Weekdays 06-18, Weekends 08-12.
Thermostat Settings: 68.0 - 72.0 F
Max Heating: 10104118.0 Btu/hr at 09:00 on 23rd January
Max Cooling: 4343195.5 Btu/hr at 16:00 on 16th July

MONTH	HEATING (Btu)	COOLING (Btu)	TOTAL (Btu)
Jan	1738618240	0	1738618240
Feb	1281165440	0	1281165440
Mar	1049789120	0	1049789120
Apr	625870528	2337277	628207808
May	181170384	85178536	266348912
Jun	14704370	252678240	267382608
Jul	0	446172128	446172128
Aug	5240486	325345984	330586464
Sep	50769244	143910736	194679984
Oct	352631520	4799974	357431488
Nov	861549184	0	861549184
Dec	1262398848	0	1262398848
TOTAL	7423907328	1260422784	8684329984
PER M^2	744759	126444	871203

Floor Area: 107296.86 ft2

RETROFIT 2: MONTHLY HEATING/COOLING LOADS
Zone: 2nd-6th floors
Operation: Weekdays 06-18, Weekends 08-12.
Thermostat Settings: 68.0 - 72.0 F
Max Heating: 7487543.5 Btu/hr at 09:00 on 23rd Janu
Max Cooling: 3242886.8 Btu/hr at 15:00 on 16th July

MONTH	HEATING (Btu)	COOLING (Btu)	TOTAL (Btu)
Jan	1240053632	0	1240053632
Feb	910082816	0	910082816
Mar	742866432	0	742866432
Apr	438787232	967502	439754720
May	122418208	62867872	185286080
Jun	8038232	187386064	195424288
Jul	0	329564512	329564512
Aug	1948499	242127456	244075952
Sep	34384444	109364216	143748656
Oct	241790144	2870198	244660336
Nov	606101440	0	606101440
Dec	894198400	0	894198400
TOTAL	5240669696	935147904	6175817728
PER M^2	525739	93813	619552

Floor Area: 107296.86 ft2

Figure 80: Space Heating and Cooling Loads
Comparisons for Existing Building and Proposed Retrofits
Sources: Autodesk Ecotect 2011, Illustrations by Author.

[136] "Southwall Technologies: Heat Mirror Insulating Glass," last modified 2013, http://www.southwall.com/southwall/Home/Commercial/Products/HeatMirrorInsulatingGlass.html.

well as rigid insulation (+R15) behind spandrel glazing. The first retrofit constitutes a 3% reduction in energy. Retrofit #2 includes the same as Retrofit #1, except Hurd Inc. Ultra-R quad cavity dual pane windows are added on the interior side. This is a high performance glazing with suspended heat mirror films that effectively create a 4-pane glazing unit. By adding these units to all windows, heat loss from conductance is substantially reduced and affords a new total energy savings near 31.7%. While this is substantial, it should be mentioned that this reduction pertains to space heating and cooling loads only.

Passive Gains Breakdown: Heat Loss and Gain

Once space heating and cooling loads have been determined, one can further evaluate the heat losses and gains with a passive gains breakdown chart. Accordingly, Figures 81 through 84 have been generated by Ecotect for comparison. Figures 81 and 83 illustrates the existing building during each season as labeled. Figure 82 represents Retrofit #1 whereby peak loading during the summer has been reduced and is indicated by the overlay/difference versus Figure 81. Retrofit #2 is represented by Figure 84 and may be compared against the existing building space loads during the heating season (Figure 83). Accordingly, the overlay/difference is substantial with proposed retrofit #2. In summary, when passive design retrofits are made for office buildings they may reduce peak heating and cooling loads. When this is true, the office building's adjusted energy use will follow the existing building's energy trends. It will do this in upward and downward swings unless peak loads are neutralized.

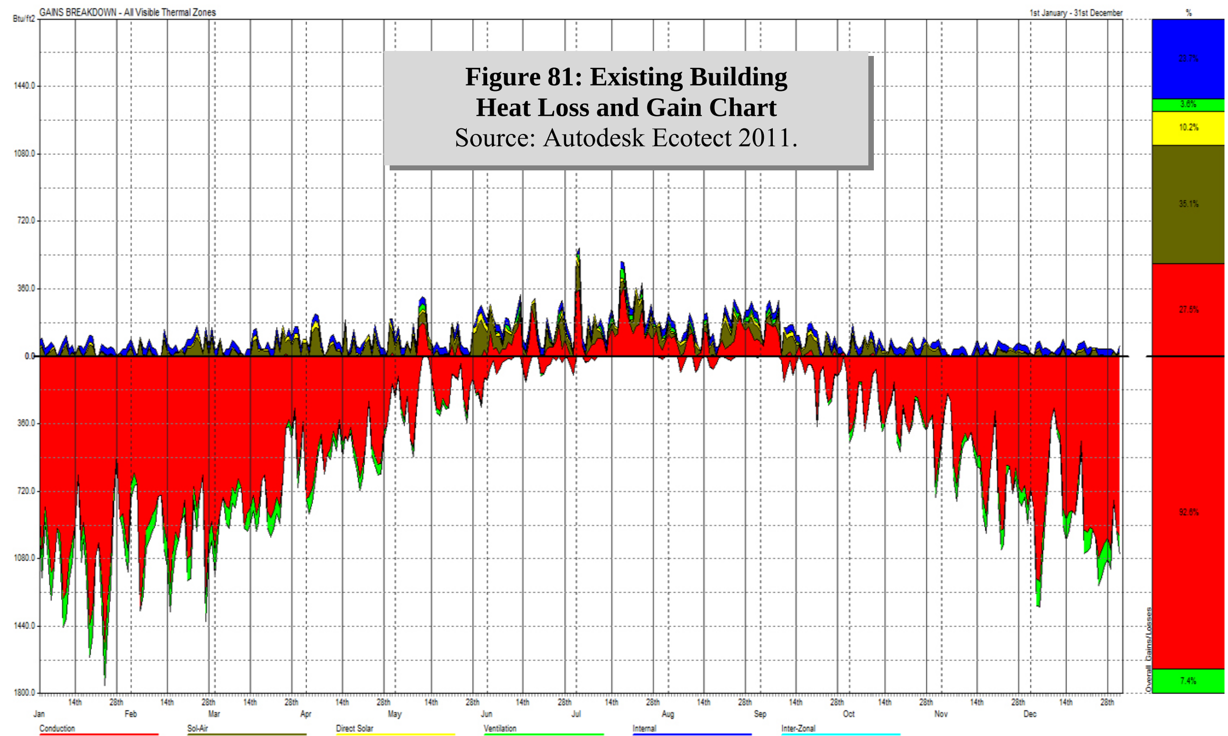


Figure 81: Existing Building Heat Loss and Gain Chart
Source: Autodesk Ecotect 2011.

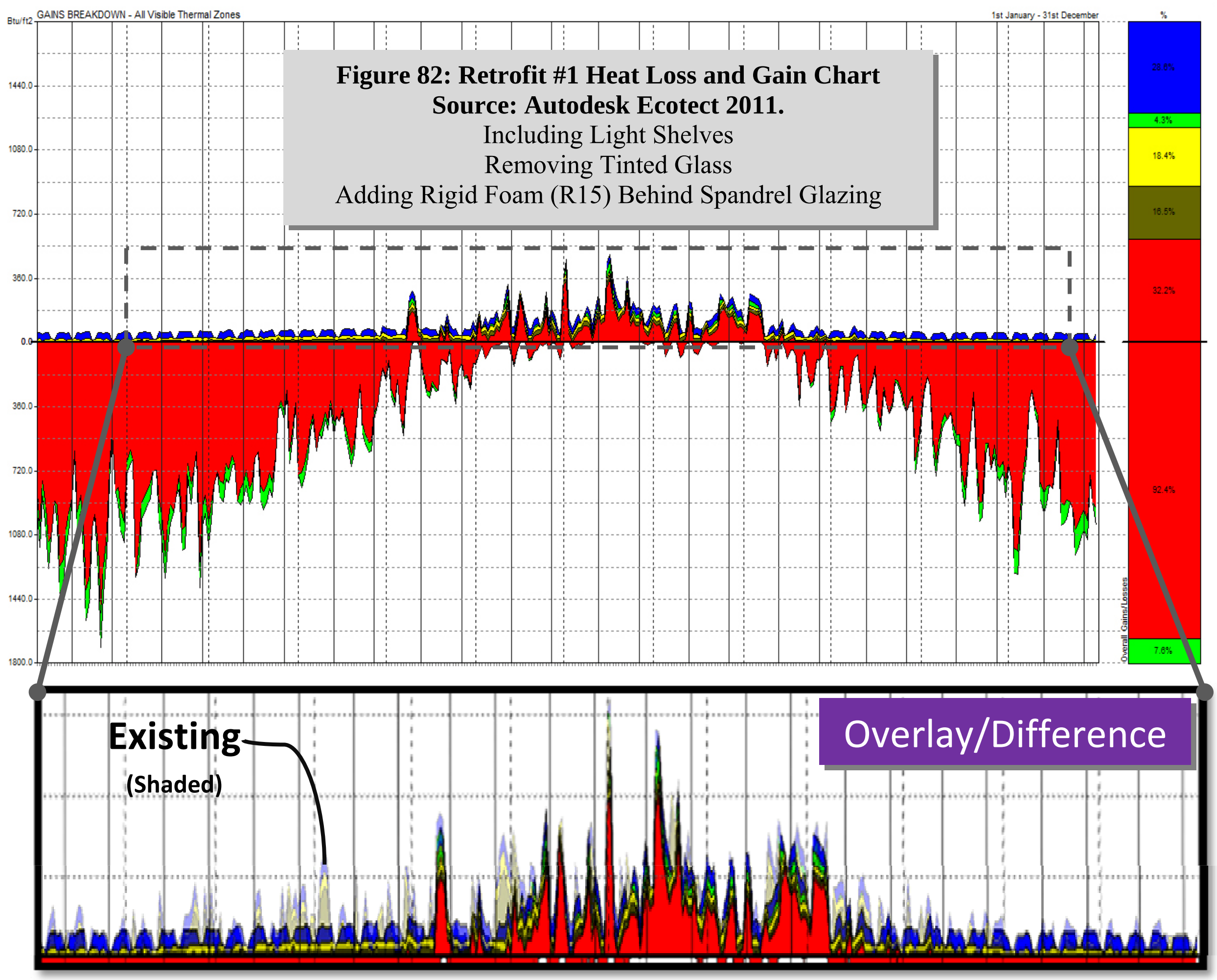


Figure 82: Retrofit #1 Heat Loss and Gain Chart
Source: Autodesk Ecotect 2011.
Including Light Shelves
Removing Tinted Glass
Adding Rigid Foam (R15) Behind Spandrel Glazing

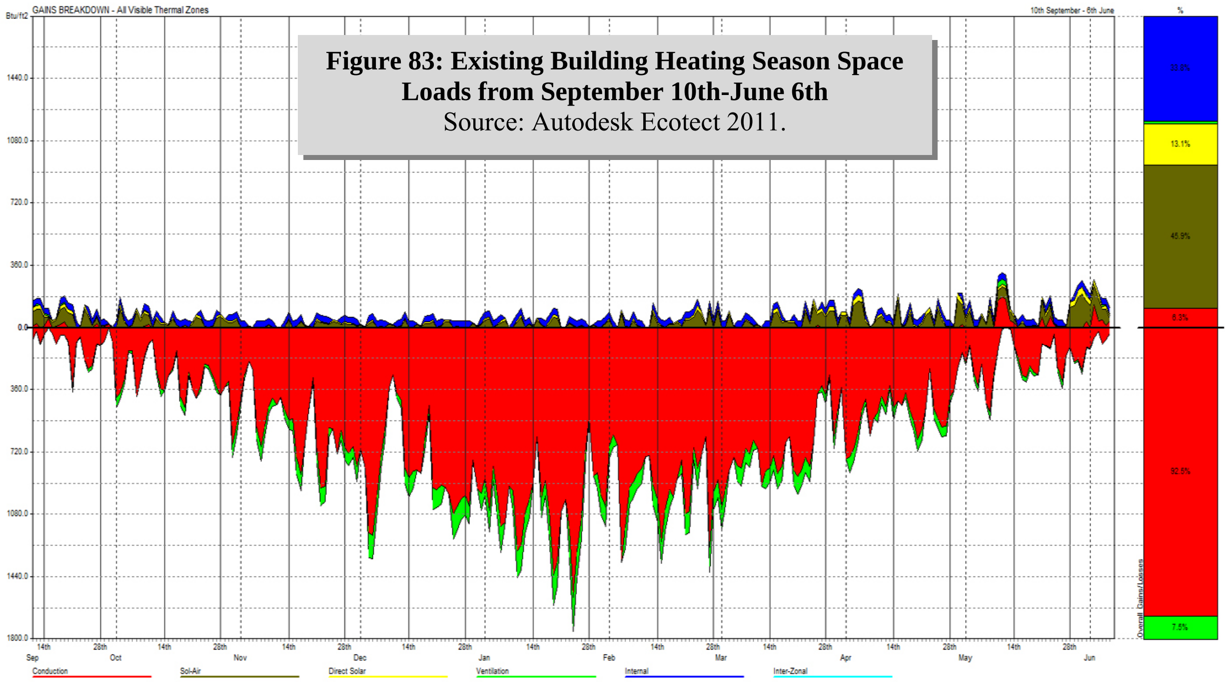


Figure 83: Existing Building Heating Season Space Loads from September 10th-June 6th
Source: Autodesk Ecotect 2011.

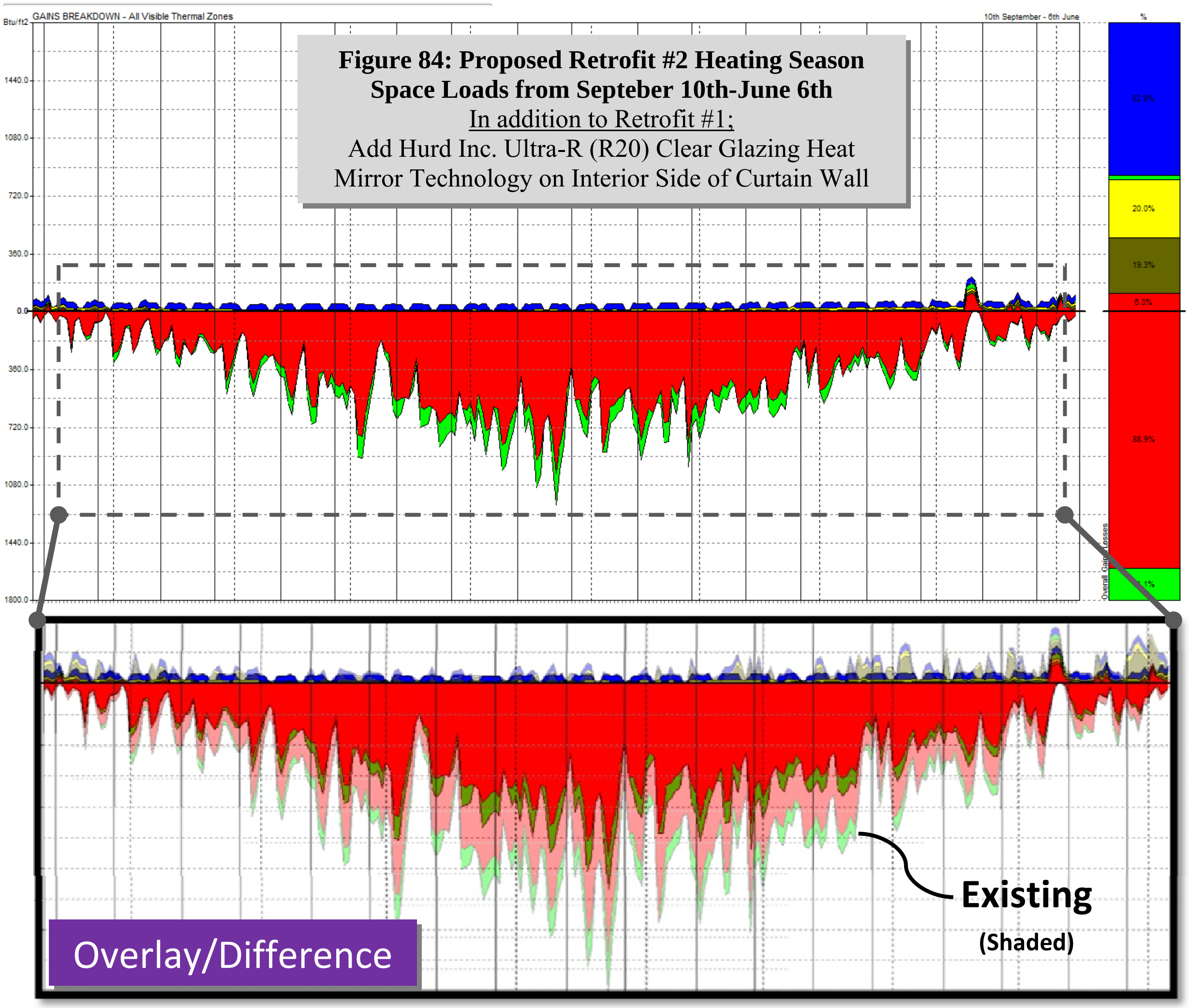


Figure 84: Proposed Retrofit #2 Heating Season Space Loads from Septeber 10th-June 6th
<u>In addition to Retrofit #1;</u>
Add Hurd Inc. Ultra-R (R20) Clear Glazing Heat Mirror Technology on Interior Side of Curtain Wall

Occupant Comfort and Energy Use Comparisons: Existing Building Versus Retrofit

pp 173-184

Energy Savings from Natural Ventilation During Passive Zone

Figure 85 represents the natural ventilation zone that can be used to determine energy savings for most office buildings in the New York Metro Area. While nearby areas may slightly differ with monthly outdoor air temperatures and prevailing wind directions, this figure can be used as a general rule of thumb to approximate the duration of natural ventilation energy savings as shown in Figure 86. This figure also references space load information from Figure 80.

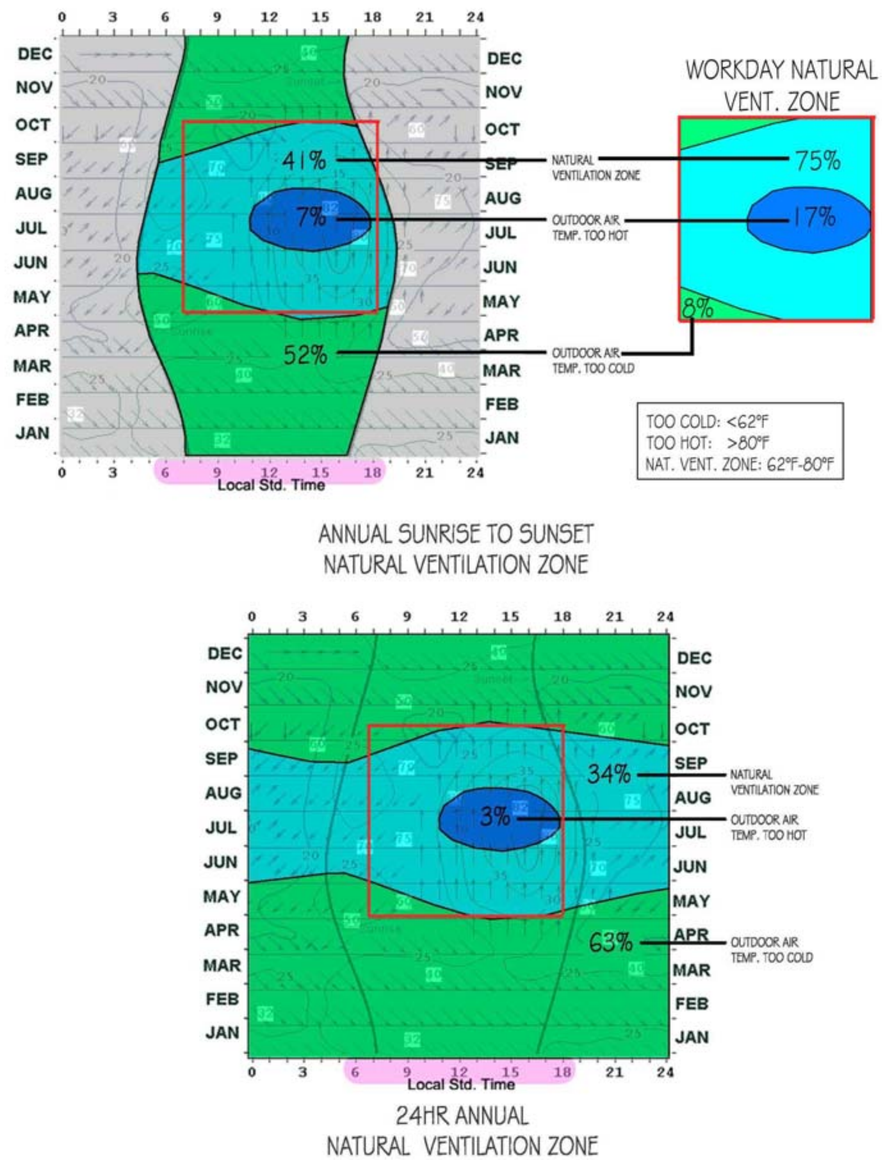


Figure 85: Annual Sunrise to Sunset Natural Ventilation Zone Approximation (%) for La Guardia Airport, NY Based on Mean Annual Air Temperature Information
Source: National Oceanic and Atmospheric Administration

Natural Ventilation Zone*:

According to Figure 85, the natural ventilation zone is approximately 41% of the year, between the hours of sunrise to sunset. Also, this zone makes up approximately 34% of the year based on an annual, 24 hour period. Lastly and most importantly, the "passive zone" is estimated as **75%** of the workday duration from May 1st through October 15th, 7:00am-6:00pm.

*% of schedule where outdoor air temperature is between 62°F - 80°F. Assumes occupants wear appropriate clothing and interior air movements are near 165 FPM (can offset occupant real feel temperature by ~11°F). See Figure 6 for clothing insulation factors and related research.

Figure 86: Workday Heating and Cooling Space Loads from May 1st-Oct. 31st

MONTH	HEATING (Btu)	COOLING (Btu)	TOTAL (Btu)
May	122418208	62867872	185286080
Jun	8038232	187386064	195424288
Jul	0	329564512	329564512
Aug	1948499	242127456	244075952
Sep	34384444	109364216	143748656
Oct	241790144	2870198	244660336 /2

Note: Workday space heating and cooling loads account for increased shading from May 1st through Oct. 31st as computed by Autodesk Ecotect Analysis 2011.

total energy

x .75 = **915,322,242 Btu**

Note: Passive zone duration extends through Oct. 15th (1/2 month).

Since "fans use approximately 1/3 of the energy required for active air conditioning systems" and they will be used in supplement to natural ventilation (Brendel 2010)...[137] The following total energy savings calculation (Figure 87) deducts fan energy, whereby the energy offset in Btu's for mechanically heating and cooling air is the energy saved.[138]

Figure 87: Annual Energy Saved Using Natural Ventilation and Appropriate Occupant Attire

total energy - fan energy

915,322,242 Btu - (915,322,242 x .33) =

energy saved

613,265,902 Btu
(Heating and Cooling Air Offset)

-OR-

179,730.5 kWh
(1 Btu = 2.9307107 x 10^{-4} kWh)

-OR-

$26,234.00
(2013 Rate: $0.146 / kWh)

Equivalent CO_2 Offset

127 Tons
(.00070555 Metric Tons CO_2 / kWh)

Equivalent Oil Offset

55 Barrels
(0.43 Metric Tons CO_2/Barrel)

Source: http://www.heatingoil.com/category/blog/commodities-markets/

[137] Michael Brendel, "The Role of Fan Efficiency in Reducing HVAC Energy Consumption," *Consulting-Specifying Engineer*, April 01, 2010.
[138] "Clean Energy Calculations and References," USEPA, last modified December 6th, 2012.

Energy Saved from Increased Natural Daylight and Off-switching

The commercial open office sector, "consisting of deep floor plates and wide expanses of undifferentiated space and a need for privacy creates tensions between overly taxed HVAC systems and lighting" (Gelfand et al. 2012).[139] This design project aims to determine the energy demand differences associated with allowing more daylight. On another note, it is recommended that a balance of privacy and daylighting be achieved by using low-height furniture systems that allow for views, paper privacy and light to travel further into the office space. Building core support spaces can then be used for more private conversations and for increased acoustics, allowing higher decibels of sound to take place during meetings or loud business functions.

Energy savings related to increased daylighting can be estimated by determining design sky illuminance, daylight factor percentages (DF) and the areas of improvement beyond a specific lighting level. Once completed, a study photoelectric off-switching of light fixtures can be evaluated for a specific zone. Accordingly, the design sky illuminance for New York City is based upon its location at 40.7° latitude, offering approximately 7,700 Lux available to the project site as shown in Figure 88.

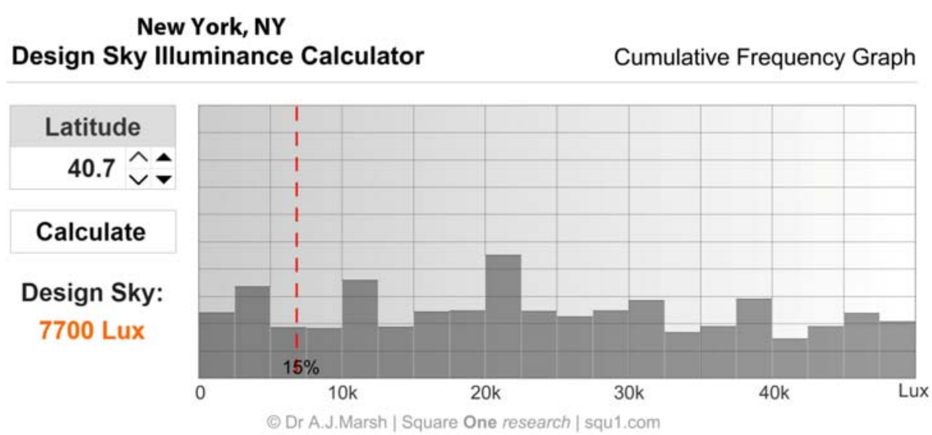


Figure 88: Design Sky Illuminance
Cumulative Frequency Graph for New York, NY Latitude
Source: Square One Research, Dr. A.J. Marsh.

[139] Gelfand and Duncan, *Sustainable Renovation Strategies,* 127.

Once the design sky illuminance has been determined, daylight factors can then be considered as a percentage of this total. As shown in Figure 89, the open office interior has been studied as an annual workday average of natural daylight from 7:00am-6:00pm, Monday-Friday (weekends omitted). The analysis grid has been elevated at 30" above the 3rd floor to represent what would be the illuminance at a common counter height. Notice the color legend starting from +4% as these locations are, at minimum, an average of 300 Lux. When this level of daylighting is achieved, off-switching of artificial light fixtures can take place.

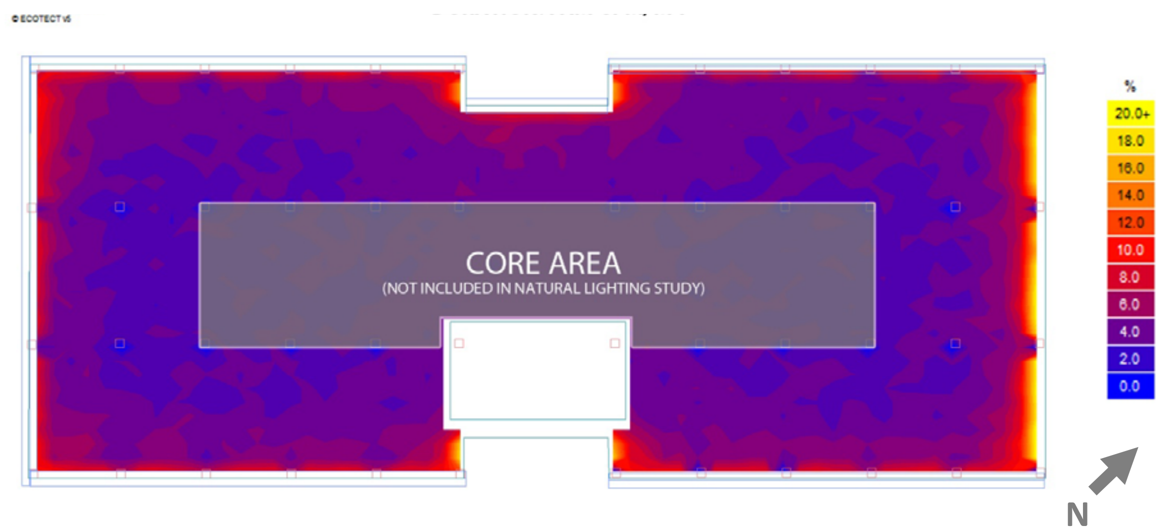


Figure 89: Annual Average Open Office Daylight Factor (%) Analysis from 7:00am-6:00pm, Monday-Friday (4% = 300+ Lux)
Source: Autodesk Ecotect 2011, Illustration Generated by Author.

When evaluating the purple to yellow contours (4%-20% DF) in Figure 89 we can notice this average is shown as a majority of the open office interior. Further studies are required to better estimate square footages for each annual average DF percentage, so that a correlation to how much light per area would otherwise be needed if this daylight was unavailable. Accordingly, Figure 90 shows the associated areas whereby the green color represents possible off-switching zones and the red areas are under recommended lighting levels (<150 Lux). The grey area represents the building core and support spaces while the white area represents the lobby, which is open to the floors below.

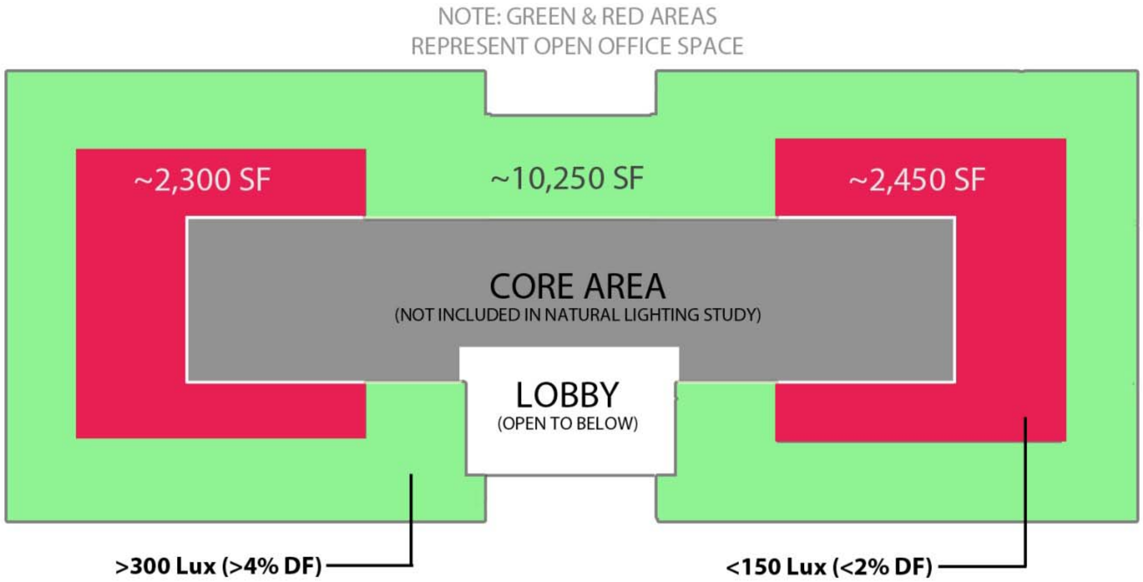


Figure 90: Open Office Annual Workday Average Lighting (Lux) Levels by Areas Offering Potential Light Fixture Off-switching (Green)
Drawing by Author.

After determining the off-switching zone as 10,250 square feet (from Figure 90), we can then determine what is the typical energy required to produce 300 Lux at a 30" high task plane. Since fluorescent 2'-0" x 4'-0" light fixtures currently exist within this building open office interior, these shall be used as the baseline to determine how much energy input is required to achieve the desired output amount. When known, this value can then be correlated to off-switching percentages during the working year to arrive at the total energy saved. Representative of these data, Figure 91 shows annual average DF versus percentage of working year lighting is off for each lighting level. Using Autodesk Ecotect's Photometric Switching calculation for this project shows an illuminance level of 300 Lux and 2.68% DF average offers the ability to turn off light fixtures for 63% of the year, as indicated by the green shaded region in Figure 91. This being the case, the next step is to arrive at the overall energy in kWh being saved during these times (Equation 4).

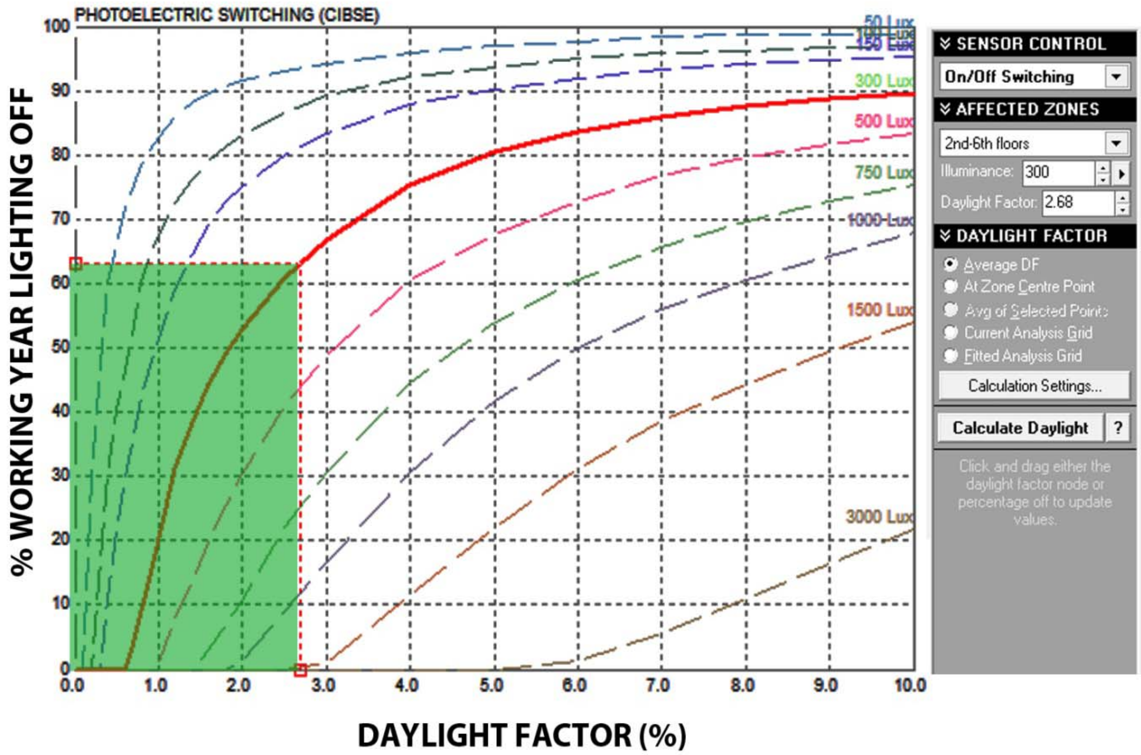


Figure 91: Percentage of Working Year Lighting Off
Versus Increased Daylight Factor (%) and Office Light Level Set at 300 Lux
Source: Autodesk Ecotect 2011, Illustration Generated by Author.

Lux to watts calculation with area in square feet:

"The power (P) in watts (W) is equal to the 0.09290304 times the illuminance (E_v) in lux (lx) times the surface area (A) in square feet (ft^2), divided by the luminous efficacy (η) in lumens per watt (lm/W), in this case *63*,[140] as a T8 GE fluorescent lamp is assumed" (RapidTables 2013).[141]

Equation 4:

$$P_{(W)} = 0.09290304 \times E_{v(lx)} \times (A_{(ft}2_{)} / \eta_{(lm/W)})$$

$$\boldsymbol{P_{(W)} = 0.09290304 \text{ x } 300 \text{ Lux x } (10{,}250 \text{ sf} / 63) = 4{,}535 \text{ W/hr}}$$

[140] Myer, M, M Paget, and R Lingard, "Performance of T12 and T8 Fluorescent Lamps and Troffers and LED Linear Replacement Lamps," Pacific Northwest National Laboratory, Operated by Batelle, last modified January, 2009.
[141] "Lux to Watts (W) Conversion Calculator," AT RapidTables, last modified 2013, http://www.rapidtables.com/calc/light/lux-to-watt-calculator.htm.

As estimated from Equation 4, nearly **4,535** Watts (w) are used for the entire floor area where off-switching may occur. When applying duration to this unit of power one can determine kilowatt hours (kWh). Since this study pertains to an office building, and in particular when it is assumingly occupied, durations of a work day and year will need to be determined in the sum of hours. Being a workday from Monday through Friday is assumed as 7:00am-6:00pm, and weekends from 8am-12:00pm there are 11 hours per weekday and 8 hours per weekend. When multiplied by 255 workdays per a 5-day/52 week year, assuming 5 holidays, there are nearly 2,805 hours whereby office lighting is assumed used.

Watts to kWh calculation

"The energy (E) in kilowatt-hours (kWh) is equal to the power (P) in watts (W), times the time period (t) in hours (hr) divided by 1000" (RapidTables 2013).[142]

<u>Equation 5:</u>

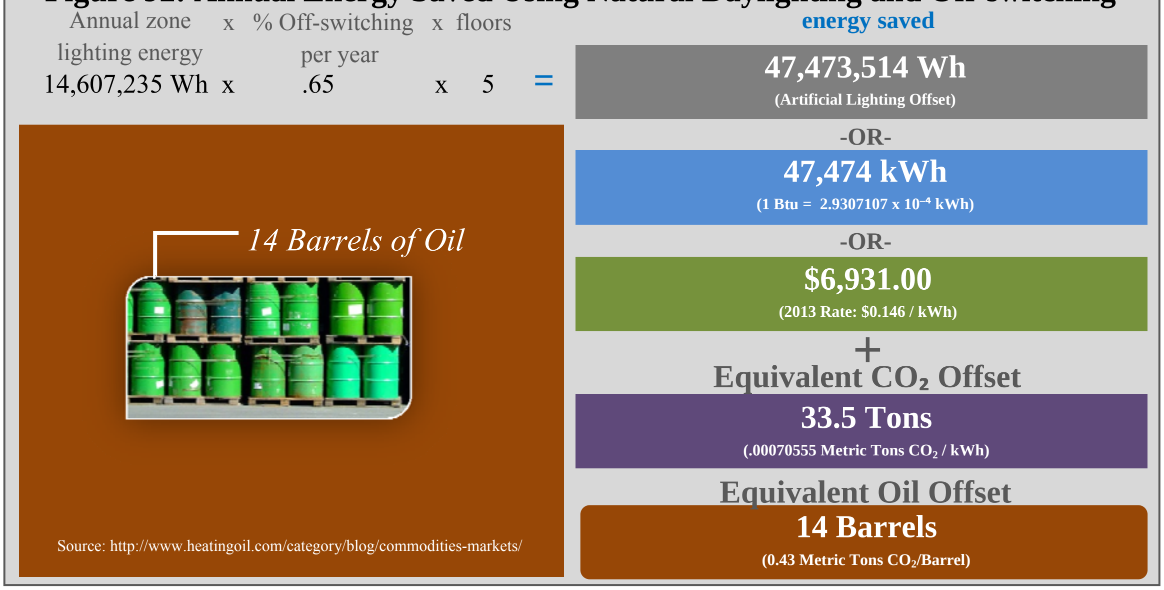
$$E_{(\mathrm{kWh})} = P_{(\mathrm{W})} \times t_{(\mathrm{hr})} / 1000$$

For weekends, 8 hours x 52 weeks equals 416 hours per year. Since this determination discounts extended hours from sunrise to sunset, this number can be considered somewhat conservative. Using 4,535 watts and 3,221 hours then dividing by 1,000 equates to kWh. From this equation, almost 14,607 kWh's (14,607,235 w) are being used for lighting zones that may otherwise be off-switched 63% of the year for each floor. When determining what 63% of this total is, we have a more accurate estimation for how much energy can be saved with increased daylighting due to the

[142] "Lux to Watts (W) Conversion Calculator," AT RapidTables, last modified 2013, http:// http://www.rapidtables.com/calc/electric/watt-to-kwh-calculator.htm.

proposed retrofit. Accordingly, nearly 9,495 kWh can be saved from off-switching on an annual basis for each floor. This savings is about $6,931.00 in electricity costs per year as there are five stacked floors undergoing the same retrofit and should have near similar results. Also, annual office building electric costs may decrease due to lower peak loads that utility companies base their billing cycles upon. For this reason, Figure 92 is clearly a conservative estimate of energy saved from increased daylighting and off-switching.[143]

Figure 92: Annual Energy Saved Using Natural Daylighting and Off-switching



Energy Saved from Decrease in Heating and Cooling Loads

Since energy cannot be "doubly saved," careful consideration to the decrease in energy used for heating and cooling associated to the proposed retrofit is necessary. Specifically, months where natural ventilation take place during the passive zone will need to be removed from energy savings for heating and cooling load improvements. The comparisons that will be removed from this energy savings estimation are mostly from May 1st through October 15th. The remaining months, October 16th through April 30th

[143] "Clean Energy Calculations" USEPA, last modified December 6th, 2012.

and parts of July and August (17%) where the outside temperature is too hot, will serve for heating and cooling load comparisons.

Accordingly, this has been outlined in red (existing) and blue (proposed retrofit) with respect to Figure 93. These calculations have been determined through Autodesk Ecotect 2011 for the existing building and the proposed retrofit. This is so the differences are equally respective to user input, climate data, durations and intensities. Also, it should be mentioned that during a normal case scenario off-switching of interior light fixtures (due to increased daylighting) will minimize internal heat gains during the year. While this is appreciated during the summer, this loss is a depreciation of heating during the winter. This specific internal heat gain or lack-thereof, however minimal, is intentionally omitted from this design project for simplicity, but might be important for larger office buildings or complexes.

EXISTING BUILDING: MONTHLY HEATING/COOLING LOADS
Zone: 2nd-6th floors
Operation: Weekdays 06-18, Weekends 08-12.
Thermostat Settings: 68.0 - 72.0 F
Max Heating: 10456669.0 Btu/hr at 09:00 on 23rd January
Max Cooling: 5326080.5 Btu/hr at 16:00 on 16th July

MONTH	HEATING (Btu)	COOLING (Btu)	TOTAL (Btu)
Jan	1764477568	0	1764477568
Feb	1273559552	0	1273559552
Mar	1052987904	1806729	1054794688
Apr	594677184	9030897	603708096
May	207067792	136375584	343443392
Jun	21443656	299372544	320816192
Jul	0	483107680	483107680
Aug	6286478	387754080	394040576
Sep	48318084	190035696	238353792
Oct	352570464	14129066	366699520
Nov	888396480	0	888396480
Dec	1298881408	0	1298881408
TOTAL	7508666368	1521612288	9030279168
PER M²	753262	152647	905909

17%

RETROFIT 2: MONTHLY HEATING/COOLING LOADS
Zone: 2nd-6th floors
Operation: Weekdays 06-18, Weekends 08-12.
Thermostat Settings: 68.0 - 72.0 F
Max Heating: 7487543.5 Btu/hr at 09:00 on 23rd Janua
Max Cooling: 3242886.8 Btu/hr at 15:00 on 16th July

MONTH	HEATING (Btu)	COOLING (Btu)	TOTAL (Btu)
Jan	1240053632	0	1240053632
Feb	910082816	0	910082816
Mar	742866432	0	742866432
Apr	438787232	967502	439754720
May	122418208	62867872	185286080
Jun	8038232	187386064	195424288
Jul	0	329564512	329564512
Aug	1948499	242127456	244075952
Sep	34384444	109364216	143748656
Oct	241790144	2870198	244660336
Nov	606101440	0	606101440
Dec	894198400	0	894198400
TOTAL	5240669696	935147904	6175817728
PER M²	525739	93813	619552

17%

Note: 17% indicates the amount of cooling loads required for July and August; assuming the remaining amount (83%) will be accounted for in natural ventilation energy savings during the summer passive zone (SPZ). Grey arrows represent column Btu values for each month and are compared between the existing building and proposed retrofit to determine energy savings related to thermal improvements.

Figure 93: Heating and Cooling Loads/Comparisons Considered for Annual Energy Savings by Incorporating Thermal Improvements (Existing Building Versus Proposed Retrofit #2)
Source: Autodesk Ecotect 2011, Illustration Generated by Author.

When adding Btu values for comparison of energy cost savings between the existing building and the proposed retrofit, the following summations have been derived from Figure 93.

Existing Building: 7,398,563,811 Btu/year

Existing Building with Proposed Retrofit: 5,318,654,067 Btu/year

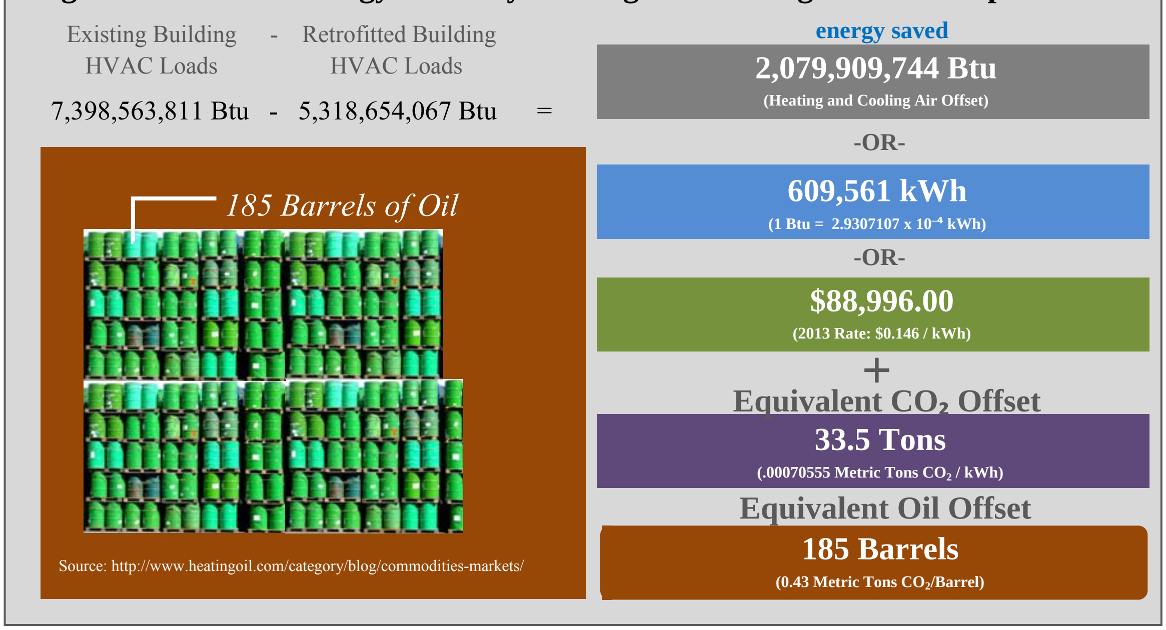
Difference: 2,079,909,744 Btu/year

Energy Use Reduction: 609,561 kWh/year

Electricity Cost Savings: $88,996.00/year

Accordingly, Figure 94 shows energy use reduction in terms of British thermal units, electricity, dollars, pollution and oil offset from the proposed retrofit thermal improvements.[144]

Figure 94: Annual Energy Saved by Heating and Cooling Thermal Improvements



[144] "Clean Energy Calculations" USEPA, last modified December 6th, 2012.

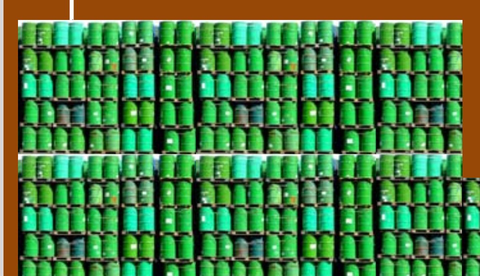
Overall Energy Savings From Proposed Retrofit

As determined in this design project, the following energy savings are conservative estimates. Specifically, they focus upon the subject building end-use differences and not the energy that will be saved from losses in power plant electrical transmission. Additionally, if the office is used outside of normal workday hours or on holidays more energy will be saved when compared to the existing building as the baseline. Also, as readily available fossil fuels deplete, the cost for drilling oil from difficult to access reserves will increase. Lastly, when there is less supply for a commodity such as fuel-oil or gas to create electricity at power plants, demand will increase and prices may rise. Although renewable energy systems are expected to increase in the future, it has been well agreed by the committee of this project that electricity prices have only gone up in previous years and are hypothesized to continue in this trend for years to come. Respectively, Figure 95 represents 2013 values and will be used to generate simple payback periods.

Figure 95: Overall Annual Energy Saved by Retrofit #2

Daylighting/Shading: 161,988,011 Btu
Thermal: 2,079,909,744 Btu
Natural Ventilation: 613,265,902 Btu
Energy Saved = Total

254 Barrels of Oil



Source: http://www.heatingoil.com/category/blog/commodities-markets/

Energy Saved

2,855,163,657 Btu
(Total Energy Offset for Daylighting/Shading, Natural Ventilation, Thermal)

-OR-

836,766 kWh
(1 Btu = 2.9307107 x 10^{-4} kWh)

-OR-

$122,168.00
(2013 Rate: $0.146 / kWh)

Equivalent CO_2 Offset

590.4 Tons
(.00070555 Metric Tons CO_2 / kWh)

Equivalent Oil Offset

254 Barrels
(0.43 Metric Tons CO_2/Barrel)

Cost Factors and Payback Period

pp 185-197

Economic Returns and Estimated Cost of Proposed Retrofit

To the low-rise open office building owner, real estate is a financial investment. A retrofit project should be "undertaken for economic benefit and be deeply rooted within the structure of business as well as taxes" (Gelfand et al. 2012).[145] Since building systems typically lose value over time due to wear and tear, life cycle and cost analysis is important for renovations. Based on this condition, "paper losses may offset income an office building generates and expiration of tax write-offs for depreciation often triggers a sale or major renovation" (Gelfand et al. 2012).[146] This is an important thing to consider since this type of retrofit project can be considered a major renovation. To start the process for economic analysis, one should estimate the cost of the proposed retrofit. Accordingly, the following product, equipment, installation, and assumptions have been prepared for the combined passive design renovation. Equations are provided for better understanding of cost estimating and can be reinterpreted for similar retrofit projects.

Products and Equipment Costs:

Daylighting/Shading Shelves:
Kawneer daylighting device: $100/linear foot (lf), per manufacturer.[147]
Wausau exterior shading device: $100/lf (estimated).

Windows:
Ultra-R fixed windows: $45/square foot (sf), per manufacturer.[148]
Ultra-R Operable Awning Windows (with screens): $65/sf, per manufacturer.[149]

[145] Gelfand and Duncan, *Sustainable Renovation Strategies,* 12-13.
[146] Ibid.
[147] John M., E-mail Message to Author, Estimated Price for Kawneer InLighten Light Shelf Product and Install, March 20th, 2012.
[148] Anonymous, Phone Conversation, Hurd, Inc., Price of Ultra-R Fixed and Operable Glazing Per Square Foot Estimate, March 20th, 2013.
[149] Ibid.

Other:

Heat coils: $15/lf.[150]

Owens Corning 3" Rigid Insulation: $2.40/sf, including overhead and profit (O+P)[151]

Armstrong Optima 2'x4' light reflective acoustical ceiling tiles, 12' inward from perimeter: $6.75/sf, per distributor.[152]

Photosensors: $85 each (ea), quantity of 10 assumed per floor.[153]

Installation Costs:

Selective Demolition:

Cost of tinted/reflective film removal and cleaning: $1.30/sf.[154]

Cost of removing existing fixed window sash for new operable window installation: $39.50 ea, including O+P.[155]

Installation:

Cost for securing interior/exterior light shelves and shading devices: $50/lf.[156]

Operable awning window installation: $89 ea.[157]

Fixed window installation: $80 ea.[158]

Cost of electrical connection of heating coil into wall: 3/4" diameter conduit $5.90/lf (assuming 120'), 4" box; $34 ea (assuming 7), switchbox: $29.50 ea. (assuming 7).[159]

Paint interior white, satin finish (2 coats): $1.41/sf, including O+P.[160]

Cost of drilling, screwing joints for each shelf heating coil: $25.50 ea.[161]

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150 http://www.morelectricheating.com/products/ROOF AND GUTTER DEICING/NUHEAT 13PK08W1.aspx

151 Phillip Waier, *RS Means Building Construction Cost Data: 71st Annual Edition*, (Norwell, MA: Reed Construction Data 2012) 218.

152 Nathan, Phone Conversation, AMS Inc., Pricing for Optima Lay in Tegular Acoustical Ceiling Tiles Per Square Foot, Honolulu HI, March 21st, 2013.

153 http://compare.ebay.com/like/261133127976?var=lv&ltyp=AllFixedPriceItemTypes&var=sbar 1/3

154 http://www.buzzle.com/articles/window-tint-removal-cost.html

155 Waier, *RS Means Building Cost*, 218.

156 John M., E-mail Message to Author, Estimated Price for Kawneer InLighten Light Shelf Product and Install, March 20th, 2012.

157 Waier, *RS Means Building Cost*, 281.

158 Ibid., 280.

159 Ibid., 551.

160 Ibid., 351.

161 Ibid., 277

Temporary Protection and Cleaning:

Temporary peel away film carpet protection: $0.26/sf.[162]

Interior cleaning after daily completion: $46/1,000 sf.[163]

Rental Costs:

Exterior scissor lift (50-60' high): $4,400.[164]

Other:

Post mounted warning construction zone sign: $24 ea, assuming 4.[165]

Warning tape barricades: $27.50, 500' per roll, assumed 2.[166]

Factored Costs:

Location Factor and Estimating Contingency:

City cost index: Queens NY, multiply by 1.29 (29% higher than US average).[167]

Contingency: 5% for unknown cost of re-circuiting existing light fixtures, constructing before/after operating hours, installing new ceiling mounted photo-sensors as required for off-switching. Note: The electrical estimate cannot be confidently made without a site visit from a licensed electrician and has been provided for cost-estimating purposes only.

Assumptions:

Tasks Assumed to be Done by Maintenance and Building Manager (no added cost):

-Replace existing acoustical ceiling tiles with Armstrong Optima "Open Plan" tiles.

-Clean interior windows and interior dust control/cleaning.

-Cost of moving around furniture: To be done after hours, if required.

General Estimating Notes:

1) Costs for work crews are included in each items built-up and unit cost.

2) Continued maintenance of light shelves/shading units assumed to be offset with lower costs for blub replacement (due to off-switching).

3) Estimate does not account for compounded interest from money saved on utility bills.

4) Since cleaning of interior/exterior glazing will be required for the existing building as

[162] Ibid., 25.
[163] Ibid.
[164] Ibid., 669.
[165] Ibid., 23.
[166] Ibid.
[167] Waier, *RS Means Building Cost*, 754.

well as the proposed retrofit, these costs should not be of substantial increase and have been omitted from this cost estimate.

5) The office is intended to operate through construction during normal business hours (if possible) and should not be affected by any continued work after hours or on weekends.

6) Nassau County, NY Sales Tax is currently 8.625% and has been omitted from the project total as products are assumed to be purchase from out-of-state distributors.

7) Non-union Overhead and Profit estimated as 20% of construction cost (Waier 2012).

8) The total area for proposed new windows is approximately 17,000 sf (for 2nd-6th floors) as determined by Autodesk Ecotect Analysis 2011.

9) Estimate assumes manufacturer suggested retail price for glazing is 20% more than actual distributors price for such quantity.

10) There is minimal redundancy in overhead and profit calculations where sources did not separate this figure from labor and materials (where noted). This results in a small over-estimation of installation costs. The larger expense for this project is due to the price of products, rather than the installation.

Equation Used for Calculating Estimate:

Equation 6:

Product Costs + Installation Costs + Factored Costs = Base Cost x Overhead and Profit + Design Fees = Total Estimated Cost

Using this equation the overall estimate for the retrofit is determined as follows:

Product Costs Per Floor:

Retrofit Costs Color Legend
Increased Thermal Performance
Increased Daylighting and Shading
Natural Ventilation and Occupant Comfort

Equation 7:

Daylighting/ Shading Shelves — Interior and Exterior, Upper and Lower

($400/lf x 500 lf)

\+ **Other Items** — Add Fixed Hurd Ultra-R Interior Windows; Add Operable Hurd Ultra-R Windows (26); Add Nutone Heating Coils; Add Owens Corning Rigid Foam Insulation

($45/sf x~3,400sf) +($65/sf.x(26x22sf/ea)) +($30/lfx500lf) +($2.40/sf.x~2,800sf)

Ceiling Mount Photo-sensors; Armstrong Optima Reflective Acoustical Ceiling Tiles

($85ea.x10) + ($5 /sf. x 12'depth x 500lf) = **$442,750** (Product Total/Floor)

Equation 8:

Solving for Combined Product Total, Location Factor and Contingency; 20% Overhead and Profit

Product Total/Floor. x 5 Floors = **$2,213,750 x 1.34 = $2,966,425 x 1.2**

= $3,559,710

Installation Costs Per Floor:

Equation 9:

+ **Selective Demolition**

Tinted Film Removal From Existing Windows and Cleaning + Existing Window Sash Removal for New Operable Awning Window Install

($1.30/sf. x~3,400) + ($39.50 x 26 windows)

Assumptions

+ **Installation**

Securing All Shelves to Interior and Exterior + New Operable Awning Window Installation + Interior/Exterior Conduit for Heating Coil + Electrical and Switchbox

($200/lf x 500lf) + ($89ea.x26 windows) + ($5.90/lf x120 lf) + ($34x7+$29.50x7)

Assumption

Interior Painting: White, Satin Finish + Screw/Drill Shelves for Heating Coil Install + New Fixed Window Installation

($1.41/sf x 2,480sf) + ($25.50ea. x (500lf/4'ea.)) + ($80ea.x (3,400sf/22sf))

+ **Temporary Protection**

Peel Away Carpet Film Adhered to Floor + Daily Interior Cleaning After Completion

($0.26/sf x 6,200sf) + ($.046/sf x 6,200sf)

+ **Rental Costs**

(1) Exterior Scissor Lift Up To 60' High Per Floor

($4,400)

Assumption

+ **Other Costs**

(4) Post Mounted Construction Zone Sign + (2) Rolls Work Zone Caution Tape

($24ea. x 4) + ($27.50 x 2) = **$134,410** (Install Total/Floor)

Equation 10:

Solving for Combined Install Total, Location Factor and Contingency; 20% Overhead and Profit

Install Total/Floor x 5 Floors = **$ 672,050 x 1.34 = $900,547 x 1.2**

= $1,080,656

Retrofit Costs by Design Strategy

This section is intended to differentiate between costs associated to each retrofit design strategy for the 2nd-6th floors of the Towers. This will be useful for simple payback period analysis to determine if a retrofit investment for energy savings is worthwhile. When evaluating the proposed simple payback periods, multiple design scenarios will be considered and compared. Estimated totals shown below represent product costs, installation costs, increased costs due to location factor, a 5% contingency, overhead and profit. Temporary protection and other costs are assumed to be equally shared for each design strategy. Each window unit has been estimated at 22 square feet of the total glazing area which is equivalent to a 4'-0" x 5'-6" glazing.

Equation 11:

Natural Ventilation and Occupant Comfort Measures*:

Product, Demo, Install, Temp. Protect., Other Costs, Factors, Floors, 20% Overhead and Profit

$$\{ [(37{,}180) + (1{,}027) + (2{,}314) + (537.33 + 95.07) + (32 + 18.33)] \times 1.34 \} \times 5 = \$276{,}065 \times 1.2 = \mathbf{\$331{,}278}$$

Equation 12:

Increased Daylighting and Shading Measures*:

Product, Demo, Install, Rental, Temp. Protect., Other Costs, Factors, Floors, 20% Overhead and Profit

$$\{ [(200{,}000 + 15{,}000 + 850 + 30{,}000) + (4{,}420) + (100{,}000 + 708 + 444.50 + 3{,}496.80 + 3{,}187.50) + (4{,}400) + (537.33 + 95.07) + (32 + 18.33)] \times 1.34 \} \times 5 = \$2{,}433{,}370 \times 1.2 = \mathbf{\$2{,}920{,}044}$$

Equation 13:

Increased Thermal Performance Measures*:

Product, Install, Temp. Protect., Other Costs, Factors, Floors, 20% Overhead and Profit

$$\{ [(153{,}000 + 6{,}720) + (12{,}363.60) + (537.33 + 95.07) + (32 + 18.33)] \times 1.34 \} \times 5 = \$1{,}157{,}534 \times 1.2 = \mathbf{\$1{,}389{,}040}$$

As a check, the calculations above should nearly equal the sum of the previous combined total. A small difference is acceptable due to marginal rounding error:

Equation 14: Checking for Accuracy of Estimated Totals

$$\mathbf{\$331{,}278 + \$2{,}920{,}044 + \$1{,}389{,}040 \approx \$3{,}559{,}710 + \$1{,}080{,}656}$$

$$\mathbf{\$4{,}640{,}362 \approx \$4{,}640{,}366 \text{ O.K.}}$$

*See "Product and Installation Costs Per Floor" for descriptions and breakdown of subtotals as shown.

New York Tax Incentives and Rebate Programs for Great Neck, NY

As part of the United States 2030 challenge for energy use reduction and other energy efficiency initiatives, the federal, state and local governments are starting to offer financial assistance for building improvements that meet their requirements. The Database of State Incentives for Renewables and Efficiency (DSIRE) as funded by the Department of Energy "...lists all current State and Federal programs that are currently providing funding for energy improvements" (Syed 2012).[168] As verified, this site includes property tax incentives and rebates for residential and commercial properties and is updated on a regular basis. Of the many forms of assistance available for energy improvements, the following funding options are available for commercial office buildings that are located in NY and particularly the city of Great Neck. Each apply to this retrofit project since the following energy improvements have been considered:

-High Performance Glazing

-Overall Building Performance

-Daylight Harvesting and Dimming (Syed 2012).[169]

Accordingly, the following pages illustrate currently available state, local, village and utility incentives that pertain to this project. These criteria will be used to project currently available tax incentives for this retrofit project and subsequently used for calculating payback periods based on initial investments discussed earlier.

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[168] Syed, *Advanced Building Technologies*, 19.
[169] Ibid.

Figure 95.1: Long Island Power Authority - Commercial Energy Efficiency Rebate Program

State:	New York
Incentive Type:	Utility Rebate Program
Eligible Efficiency Technologies:	Building Controls, Building Envelope
Applicable Sectors:	Commercial, Industrial, Nonprofit, Schools, Institutional
Amount:	Custom: Varies Widely
Maximum Incentive:	Whole Building: $400,000 per building annually
Equipment Requirements:	See program web site for full requirements
Ownership of Renewable Energy Credits:	LIPA retains ownership of all rights to existing and future emissions credits, renewable energy credits, green tags, tradable renewable certificates and/or any and all other environmental benefits associated with the installation of the eligible equipment.
Web Site:	http://www.lipower.org/efficiency/commercial.html

Major renovations of existing buildings and new construction projects are both eligible for this program, with new construction incentives being slightly reduced compared to existing building incentives. There are several paths to choose from in the program, each one designed to fit the needs of a particular customer.

-The Custom Approach provides funding for more complex energy-saving measures, perhaps measures unique to the building or business, which are not covered under the prescriptive approach.

-The Green Building Approach allows businesses to pursue options that fully integrate building envelope and operating systems to produce a building as energy efficient as current technology and design allows.

Incentives will cover a portion of the additional design and equipment expenses required to create an exemplary building. For customers exploring the custom approach or the whole building design approach LIPA will provide
up to $10,000 in technical assistance services, including consultants to help businesses choose and implement energy-efficient measures and equipment. For more complex projects, LIPA will provide 50 percent of any additional planning costs, up to $50,000. Follow all steps on rebate applications if pursuing incentives.

Source: http://www.dsireusa.org, Last Modified July 2nd, 2012, Accessed 03/18/2013.

Figure 95.2: Federal Energy-Efficient Commercial Buildings Tax Deduction

State:	Federal
Incentive Type:	Corporate Deduction
Eligible Efficiency Technologies:	Lighting Controls/Sensors, Building Insulation, Windows, Comprehensive Measures/Whole Building
Applicable Sectors:	Commercial, others
Amount:	\$0.30-\$1.80 per square foot, depending on technology and amount of energy reduction
Maximum Incentive:	\$1.80 per square foot
Equipment Requirements:	Not specified, but building must be certified as meeting specific energy reduction targets as a result of improvements in interior lighting; building envelope; or heating, cooling, ventilation
Start Date:	1/1/2006
Expiration Date:	12/31/2013
Web Site:	http://www.efficientbuildings.org
Authority 1: **Date Enacted:** **Date Effective:** **Expiration Date:**	26 USC § 179D 8/8/2005 (subsequently amended) 1/1/2006 12/31/2013

The federal Energy Policy Act of 2005 established a tax deduction for energy-efficient commercial buildings applicable to qualifying systems and buildings placed in service from January 1, 2006, through December 31, 2007. This deduction was subsequently extended through 2008, and then again through 2013 by Section 303 of the federal Energy Improvement and Extension Act of 2008(H.R. 1424, Division B), enacted in October 2008. Deductions of \$0.60 per square foot are available to owners of buildings in which individual lighting, building envelope, or heating and cooling systems meet target levels that would reasonably contribute to an overall building savings of 50% if additional systems were installed.

Source: http://www.dsireusa.org, Last Modified October 1st, 2012, Accessed 03/18/2013.

Payback Periods and Design Fees by Type of Passive Design Retrofit

Natural Ventilation and Occupant Comfort Measures

Retrofit Cost		7.5% Design Fees		Annual Energy Savings		Payback Period (Years)	
($331,278	x	1.075)	/	$26,234.00	=	14	Equation 15

Increased Daylighting and Shading Measures

Retrofit Cost		7.5% Design Fees		Annual Energy Savings		Payback Period (Years)	
($2,920,044	x	1.075)	/	$6,931.00	=	453	Equation 16

Increased Thermal Performance

Retrofit Cost		7.5% Design Fees		Annual Energy Savings		Payback Period (Years)	
($1,389,040	x	1.075)	/	$88,996.00	=	17	Equation 17

Combined Retrofit Strategy (without any incentives)

Equation 18

Combined Retrofit Cost		Combined Annual Energy Savings		Payback Period (Years)
$4,988,389	/	$122,161	=	40.8

When evaluating combined payback periods, including the maximum amount of currently available NY State, Federal and Utility incentives, the following approximations can be made:

Combined Retrofit Strategy (with **100%** of available incentives)

Equation 19

Combined Retrofit Cost		Federal Commercial Tax Incentive		Combined Annual Energy Savings		Long Island Power Authority		Payback Period (Years)
$4,988,389	-	($0.60/sf x 107,000sf)	/	($122,161/yr	+	400,000/yr)	=	9

Combined Retrofit Strategy (with **50%** of available incentives)

Equation 20

Combined Retrofit Cost		Federal Commercial Tax Incentive		Combined Annual Energy Savings		Long Island Power Authority		Payback Period (Years)
$4,988,389	-	($0.30/sf x 107,000sf)	/	($122,161/yr	+	200,000/yr)	=	15

Note: Professional design fees have been assumed at 7.5% of construction cost. Payback periods with a decimal have been rounded up or down to the next closest year. Electricity rates are assumed to remain the same over the duration of the payback period. This is a conservative, estimate since electricity rates are known to consecutively increase year over year.

Combined Retrofit Strategy (with **25%** of available incentives)

Equation 21

Combined Retrofit Cost		Federal Commercial Tax Incentive		Combined Annual Energy Savings		Long Island Power Authority		Payback Period (Years)
$4,988,389	**-**	**($0.15/sf x 107,000sf)**	**/**	**($122,161/yr**	**+**	**100,000/yr)**	**=**	**22**

Combined Retrofit Strategy (**100%** of Federal incentive only)

Equation 22

Combined Retrofit Cost		Federal Commercial Tax Incentive		Combined Annual Energy Savings		Payback Period (Years)
$4,988,389	**-**	**($0.60/sf x 107,000sf)**	**/**	**($122,161/yr)**	**=**	**40**

Summary:

According to the payback periods previously shown in Equations 15 through 22, it is hopeful that this custom retrofit project can at least take advantage of 50% of available incentives. As previously determined, the energy savings in kWh is projected to be near 32% annually for reduced heating, cooling and lighting loads combined. In my own opinion, this 50% rebate goal is therefore a realistic expectation for this amount of energy savings.

At the local level, the utility provider offers an incentive as annual electricity cost reduction (Figure 96). At the federal level, reimbursements are available as a tax rebate per floor area (Figure 97). This retrofit in particular would have to go through verification and approval by United States Energy Information Agency as well as the Long Island Power Authority to see what their *custom* energy savings rebate would amount to.

As indicated by previous calculations, the federal incentive is miniscule compared to the local utilities incentive. On this note, there are no state incentives currently available, however there are programs currently underway for existing buildings that achieve LEED certification. The economic incentive that has recently been approved with legislation, but not adopted by any local village or town, allows for substantial annual property tax deductions which annually depreciate according to a proposed schedule. It is with my understanding as a LEED Accredited Professional that the proposed retrofit will likely achieve LEED Certification for Existing Buildings if plumbing fixtures are upgraded and prerequisite requirements are met.

Research and Design Project Findings

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Discussion:

Researching climate data and passive design principles are vital to determining an effective passive design retrofit strategy for an existing low-rise open office building. This is particularly true for buildings located in a variable climate as discussed in this research and design project. By evaluating existing passive design retrofit typologies and mixing and matching design ideas, triangulation of an idealized retrofit scenario was made and called the "movable rhombus." Based upon this foundational research I was able to move to the design phase of this project and select a typical office building to propose a combined passive retrofit to. I then evaluated retrofit strategies based on feasibility, function, cost, environmental impact, and annual energy savings. This was in part done with Ecotect Analysis 2011 software and with cost estimating strategies from RS Means and the United States Department of Energy to develop simple payback periods relating to available tax rebates and incentives.

This project illustrates that a modern low-rise open office building in the NY Metro area may simply use passive design strategies to conserve energy. This design project also indicates that this type of building lacks respect to the climate, which makes passive design retrofit strategies more practical to consider. This type of building envelope upgrade is based on the climate subjects of sun, wind, light and air temperature. It is very specific to passive design strategies that improve the building envelope by considering energy use reduction alongside improvements in occupant comfort. The Towers in Great Neck N.Y., as studied, has an entirely fixed curtain wall envelope and tinted/reflective insulated double-glazing, is well sealed, has insulated walls and still offers room for improvement. When compared with similar buildings that may have lower thermal performance, leaky window seals, un-insulated windows and walls, or even wear and tear that requires replacement, this building is a conservative demonstration of energy reduction for this building type. The proposed retrofit, as designed and evaluated in this research project, amounted to a custom design for the Towers, located in Great Neck, NY. The findings and strategies may also be re-evaluated for other existing and new office buildings sharing similar location, construction, climate and orientation. Additionally, the methodology for determining a combined passive design strategy may be reapplied to any type of building design so long as micro-climate information has been reconsidered.

From a practical approach, the best type of passive design strategy for The Towers has measures for energy savings, increased daylighting, increased shading, natural ventilation, solar radiation and reduced heating and cooling loads simultaneously. The retrofit, as proposed in this design and research project, is capable of doing all this while maintaining a substantial amount of occupant views to the outdoors. Regarding the proposed changes to the existing subject building envelope it appears that aesthetics and structural integrities have not changed by much, according to Figure 96. Alternatively, load capacities will still need to be reviewed by a professional structural engineer.

The costs for the proposed retrofit products, installation, location factor, contingency and a contractor's overhead and profit were more than I initially suspected. The overall estimated cost of the combined retrofit strategy was determined to be $4,988,389. This type of retrofit offered an annual electricity cost savings of $122,161, which seemed minimal, compared to the initial investment an owner would make. When evaluated for payback period durations I established a method to determining whether each strategy was a worthwhile. Accordingly, payback periods that are less than 10 years are considered well worth it. Periods between 10-15 years are considered acceptable, and between 15-20 years are debatably worth it.

The proposed combined retrofit strategy is considered to have an acceptable payback period of 15 years, so long as 50% of available tax and utility cost rebates are available after construction completion. When evaluating each passive design retrofit strategy individually, and without rebate, the following outcomes have been determined. Retrofitting an office building for thermal improvements of rigid foam insulation (R-15) and adding high-performance (R-20) windows is debatably worth it. On the other hand, utilizing natural ventilation during appropriate outdoor air temperatures and asking occupants to wear the right type of clothing has an acceptable payback period of 14 years. This is with consideration of simultaneously using active air conditioning for air circulation only. Effectively, retrofitting an existing office building for daylighting is clearly not worth it financially, but it does go to mention that occupant comfort and improved productivity that is well associated to improved daylighting is not scientifically measurable. It is with my recommendation that this retrofit be considered as a combined strategy, rather than individually for the sole purposes of payback periods. My proposal is grounded upon improving office environments while saving energy. As proven, the proposed retrofit can economically do both if annual rebate incentives are in the range of +4% of the total construction cost.

If the combined passive retrofit strategy was considered without rebates, it would be a bad investment decision, having nearly a 40 year payback period. This does not mean that this should not be considered at all though, as the subject building is nearing 32 years old today. Accordingly, this type of combined strategy is extremely worthwhile for new construction since a new office building estimate would compare cost differences between product and installation only. This initial added cost difference for incorporating a combined passive design strategy is minimal and would be overwhelmed by energy cost savings in the amount this design project has indicated.

Assuming this passive design retrofit were to take place and construction can be completed in one month's time, the following estimations are made. Almost 837,000 kWh's and more than $122,000 can be saved by May, 2014. This is in addition to more than 590 Tons of CO_2 diverted and is equivalent to offsetting the use of fossil fuels by an amount of 254 barrels of fuel-oil used to create the same quantity of electricity.

Conclusions:

Ultimately, the proposed retrofit will improve occupant comfort by minimizing the boundary between indoor and outdoor environments when achievable. This is possible with the use of clear glazing for increased and accurate color depiction of the outdoor environment as viewed through the building envelope. Also respective is the introduction of the sun into the office in the form of diffuse and indirect daylight while minimizing glare and ultra-violet rays. This is possible with the inclusion of shading devices, light shelves and low-emissivity coatings that have been studied from sunrise to sunset. Lastly, desired winds and air temperatures are now welcomed into the office from May through October by incorporating natural ventilation. This additional feature did not exist for The Towers and makes a great difference in mitigating the indoor and outdoor boundary. When heating loads increase and natural ventilation isn't possible, the addition of quad-cavity heat mirror film windows improve thermal performance of the building envelope. This is related to minimizing heat loss from conduction (through glass) during the winter. Figure 97 shows how these components can work side-by-side to achieve occupant comfort and increased energy efficiency.

Also as proven, occupants have the ability to better respond to the weather by wearing the right clothes and manipulating their workspace. As a direct result, they will also help to save energy and our environment when doing so. Since existing modern buildings are a majority of 1970's to present open office environments in the New York Metro area, there is a substantial opportunity to reduce energy use by incorporating passive design strategies into these building envelopes. This is particularly true for the modern low-rise open office building (MLOOB) as promoted in this research project. If we are to lessen the environmental effects of existing, current and future modern office buildings in an economical manner, one must start from knowing how to economically retrofit an existing building in a variable climate. Only then can they make energy reduction goals worthwhile to a corporation or building owner in this region. While it may seem like a substantial complexity, there are simple rules of thumb that can be followed and certain things a building designer should keep in mind.

In general, glass curtain wall low-rise office buildings with an east-west orientation offer better passive design retrofit payback periods compared to those with an angular orientation. This is because the amount of linear footage for daylighting and shading devices can be reduced. Respectively, exterior devices may only be needed for southern orientations and can utilize interior control mechanisms for the east and west facades. This is because the sun angle duration affecting east and west exposures will be minimal, making exteriorized devices less essential. The entire north-facing facade can virtually be left alone or peeled of its window tint for increased diffuse daylighting. This substantial reduction in the quantity of apparatus means the initial investment will be much less and payback periods will be shortened. In the case of office buildings with oddly shaped, or irregular curtain-wall systems this notion may need to be reconsidered.

Also in general, if a MLOOB envelope has leaky window seals or lacks insulation behind spandrel glazing, these are additional opportunities that can be easily remedied. By adding rigid foam insulation and resealing windows with caulk, this is a quick fix to a big problem. It should not take much effort for this type of installation though, as rigid foam is very lightweight and is available in 3" thickness which equates to a resistance value of R-15. Since modernized office buildings typically have suspended acoustical ceiling tiles that are removable, insulating spandrel glazing above the ceiling is usually an easy task. Re-caulking windows is even easier undertaking and can be done fairly quickly. Ensuring a complete seal of these building products to the existing building is critical though, as air gaps and inconsistencies will lead to convective air loops between materials and therefore more energy loss if these products are not installed correctly.

If a MLOOB envelope is found without operable windows, replacing such windows with multi-cavity high-performance operable windows is a worthwhile investment. For one, the open office building designer can achieve increased thermal performance from higher resistance values that reduce heat loss from conduction during the winter. Secondly, these windows can then be used to bring in outdoor air temperatures between 62ºF and 80ºF from May through October and help circulate outdoor air through the open office interior. Awning windows are highly recommended for this purpose and can be used to control wind inflow and help protect the office interior from rainfall events. This window type is even further recommended for the New York Metro area when shading and daylighting measures are being considered. Awning windows can work with horizontal shading and daylighting devices, even when fully open. Awning windows concurrently allow for bug screens to be used and is therefore the most suitable window typology for a modern low-rise open office in this region. This is especially true for MLOOB envelopes that are adjacent to trees, shrubbery, grass, flowers and other pollen-producing plants. These factors are deemed micro-environmental and are very important considerations that a passive building envelope retrofit designer should have in mind. The recommendation is not to replace all existing fixed windows with operable windows, rather a small quantity of 20% is considered sufficient, so long as they are staggered with respect to their locations in a floor plan.

Solar radiation is another important consideration in the New York Metro area and can be of advantage for MLOOB envelopes that have clear glass curtain wall systems. Not only will daylight transmittance be increased, but more solar radiation can be absorbed into the office interior during the winter when it is needed most. Although this is true, one will notice that during the winter solar radiation is minimal in comparison to the summer and is available for much shorter durations of the workday. This being the case, it should not be a determining factor in the decision to incorporate passive design strategies into the building envelope. It should rather be used as a passive design strategy to keep in mind and not deviate from when possible. With any passive design strategy, glare should be of concern and can be simply controlled by mechanisms that allow user adjustment. Such considerations of interior rotatable light shelves or other interiorized mechanisms may come in handy during such conditions.

In description of the most opportune passive design retrofit for the MLOOB envelope in the New York Metro area, the following issues can be used to identify which building is a better target. If the subject building has broken windows, leaky window seals, single pane or tinted glass (or a combination thereof) and has an east-west orientation, there is a major opportunity. If the building lacks operable windows, this condition is the next biggest prospect for payback periods and energy efficiency improvements. If the building has a large open-office floor plan, and an extruded aluminum curtain wall system a compounding opportunity is presented. This is because the interiorized office spaces share the building envelope as a moderating boundary between the indoor and outdoor environment. This is where heat losses and gains, as well as daylighting, shading, views, occupant well-being and comfort also come into question. Since the building envelope is made of a very long-lasting and easily drillable rigid material, the proposed retrofit can be considered more practical and less of a hinder to an existing building facade both structurally and for longevity.

To be clear of any misconception, a building that uses shading or daylighting devices by itself, does not mean that the facade is energy efficient. It could actually mean the opposite if the exteriorized units were ill-considered in the first place. More attention should therefore be focused on the glazing and curtain wall system. However, if one knows a thermal break exists in a aluminum curtain wall framework, this does not by itself mean that the building envelope is high performance. It may actually mean there is an even larger opportunity available to correct the next weakest thermal link. If multi-cavity glazing is added to the interior or exterior side of this modernized framework, no longer will the weakest link for heat loss and gain be the windows. In this case, the weakest thermal link can be improved by high-performance building products which afford combined resistance values that are higher than most walls (R-25). This storm window strategy can work together with adjacent building envelope systems for an overall solution. This method can directly reduce the highest amount of energy loss for this building type, which is due to the conduction of glass temperature from hot to cold. This type of retrofit also has the ability to reduce air infiltration due to increased air cavities and double-sealing of window sashes within the existing curtain wall framework. Likewise, less conduction will occur for the aluminum framework as the surface area is being further encapsulated with additional storm windows in place. This can be compared to a sandwich of windows between an otherwise voided aluminum framework. After the additional storm window is added on the interior side of the building envelope, there will be less interior surface area of aluminum. One must pay close attention to condensation issues when making these decisions though. It is therefore recommended that the existing windows be fully sealed and cleaned before new windows are installed.

Inevitably, there will be some modern low-rise open office building envelopes in the New York Metro area that are more economical to retrofit with passive design strategies than others. As we move towards a more sustainable future with hopes that incentives continue to grow at the local, state and federal levels there is still hope for building envelope retrofit projects that may be less practical. Either way, a major improvement can still be achieved without economics and it pertains to the reason we make buildings in the first place; for the sheltering and comfort of people. If this was not the case for office buildings, we would otherwise work outside on a cloudy, windy or sunny day of the winter or summer with rain, snow, sleet or hail. Respectively, a retrofit that has the human factor as its foundation shall be considered successful by itself and only more purposeful based on economics.

Design Project Rendering

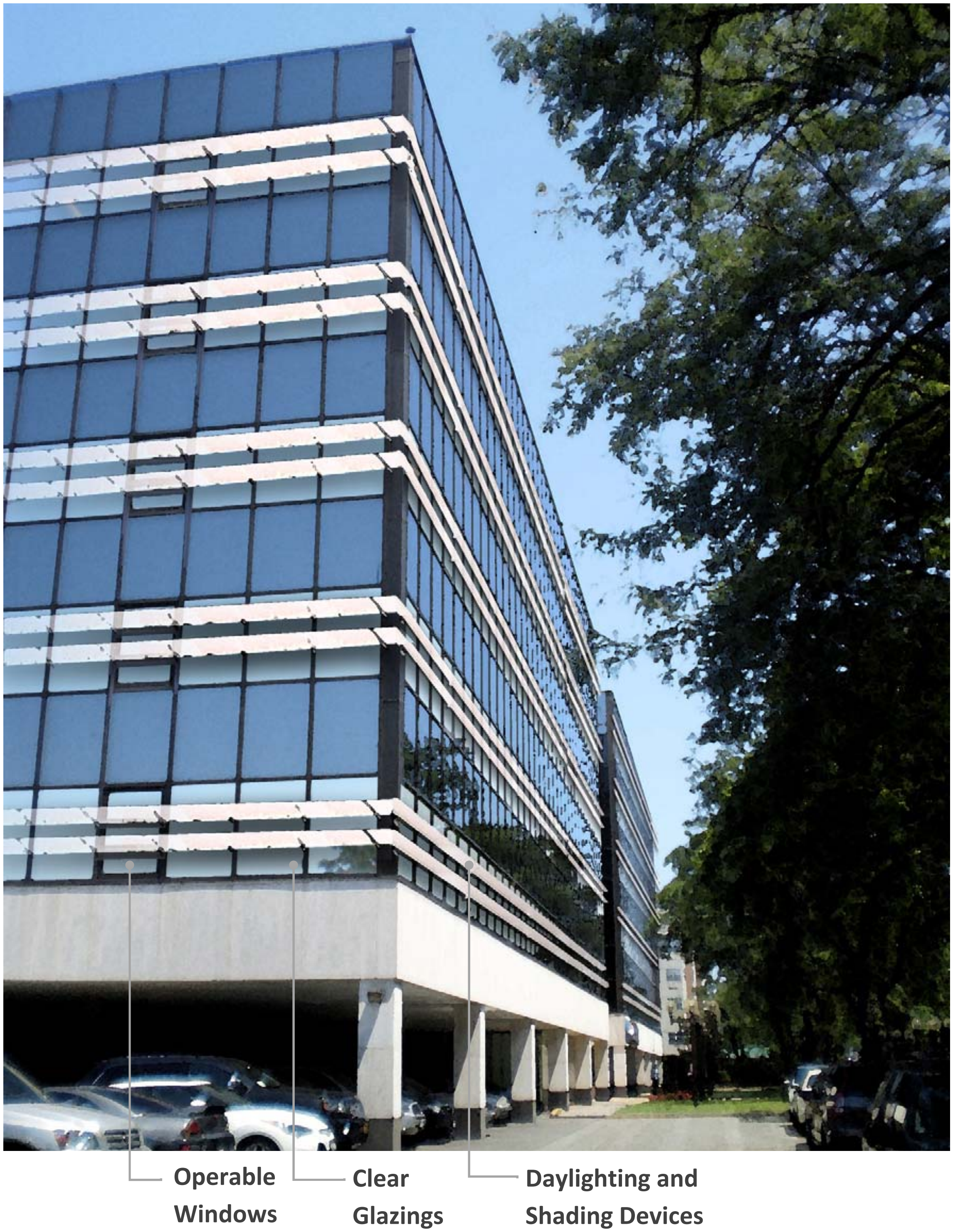

Figure 96: Proposed Combined Passive Design Strategy as Augmented Reality
Original Photo and Rendering by Author

Research and Design Project Combined Retrofit Strategy (Perspective)

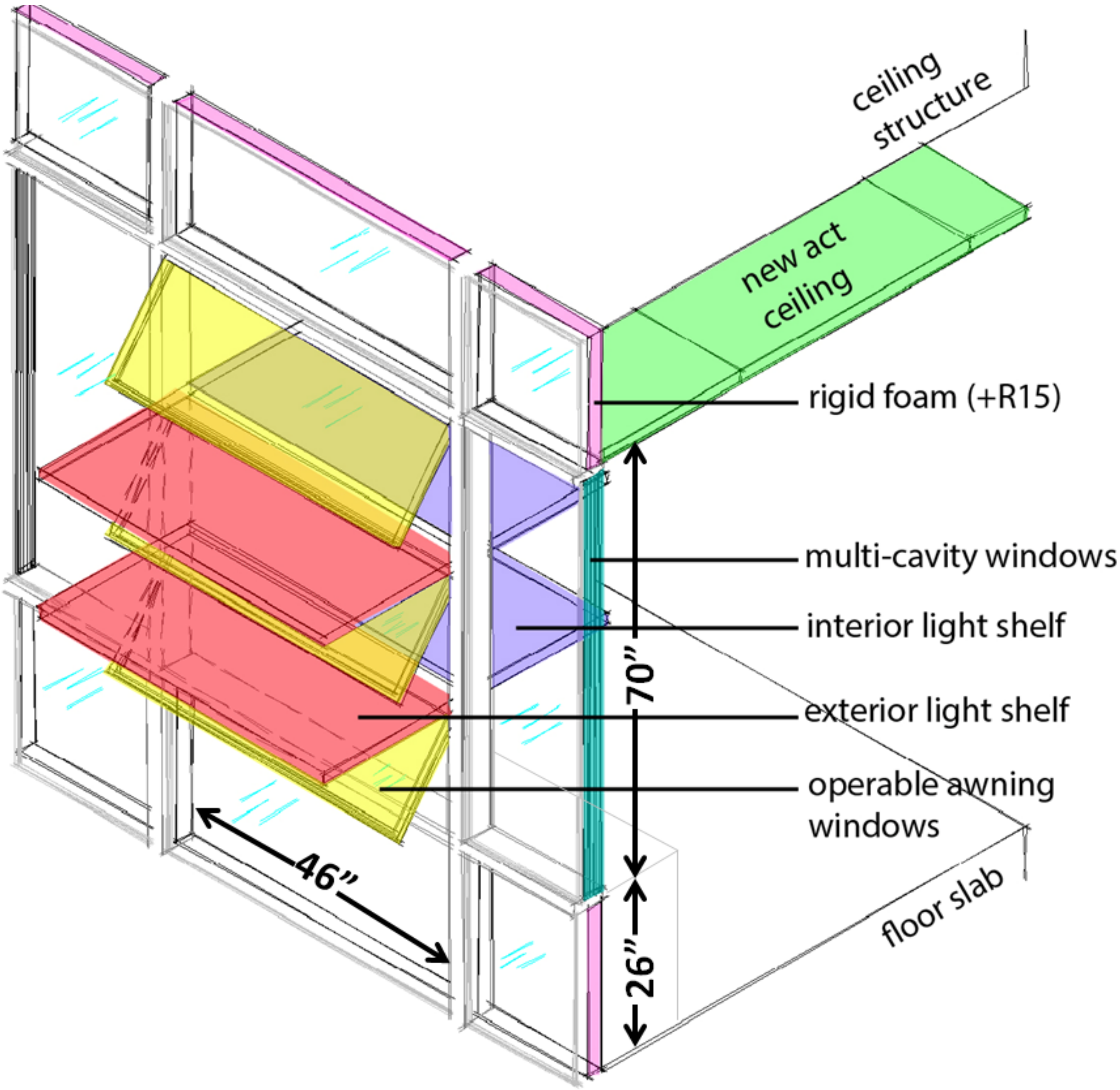

Figure 97: Combined Strategy for Increased Daylighting, Shading, Natural Ventilation, Thermal Performance, Acoustical Performance and Occupant Views.
Source: Drawing and Design by Author

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